Instituto Universitario
de Neurociencia
Universidad de La Laguna

FACULTAD DE PSICOLOGÍA Y LOGOPEDIA

DEPARTAMENTO DE PSICOLOGÍA COGNITIVA, SOCIAL Y ORGANIZACIONAL

INSTITUTO UNIVERSITARIO DE NEUROCIENCIA (IUNE)

Spatiotemporal Dynamics of Disgust Processing in Language

Tesis doctoral de la Universidad de la Laguna

Beixian Gu

San Cristóbal de la Laguna, 2020

El Dr. Manuel de Vega Rodríguez y el Dr. David Beltrán Guerrero, directores de la tesis de Beixian Gu titulada ¨Spatiotemporal Dynamics of Disgust Processing in Language¨ aprueban la lectura de dicha tesis al considerar que cumple con las exigencias científicas y formales necesarias para su presentación.

La Laguna, 16 de Noviembre de 2020

Dr. Manuel de Vega Rodríguez

Dr. David Beltrán Guerrero

Instituto Universitario
de Neurociencia
Universidad de La Laguna

FACULTAD DE PSICOLOGÍA Y LOGOPEDIA

DEPARTAMENTO DE PSICOLOGÍA COGNITIVA, SOCIAL Y ORGANIZACIONAL

INSTITUTO UNIVERSITARIO DE NEUROCIENCIA (IUNE)

Spatiotemporal Dynamics of Disgust Processing in Language

Tesis doctoral de la Universidad de la Laguna

Presentada por

Beixian Gu

Directores:

Dr. Manuel de Vega Rodríguez

Dr. David Beltrán Guerrero

San Cristóbal de la Laguna, 2020

This thesis was supported by the Spanish Ministerio de Ciencia, Innovación y Universidades (Grant RTI2018-098730-B-I00), the European Regional Development Funds, and the Research Funds for the School of International Education at Dalian University of Technology (Grant No. SIE18RZD1).

Acknowledgement

Firstly, I would like to express my sincere gratitude to my advisors Dr. Manuel de Vega and Dr. David Beltrán for their continuous support of my Ph.D study and related research, for their patience, motivation, and immense knowledge. Their guidance helped me in all the time of research and writing of this thesis. I could not have imagined having better advisors and mentors for my Ph.D thesis.

My sincere thanks also go to Dr. Huili Wang, who provided me relevant information to apply for the Ph.D program at the University of la Laguna, and who gave access to the laboratory and research facilities in China. Without her precious support it would not be possible to conduct this research.

I thank my fellow labmates in for the stimulating discussions, for all the days we were working together, and for all the fun we have had in the last three years. Also, I thank my colleagues in Dalian University of Technology and Liaoning Normal University for enlightening me the first glance of ERP data collection and processing, and all the participants to my experiments for their excellent cooperation.

Finally, I would like to thank my family and friends for supporting me spiritually throughout writing this thesis and my life in general.

Index

PART I. THEORY 1

Introduction 2

The Embodiment Approach to Emotions 3

The Emotion of Disgust 6

Learning Words' Emotional Meanings 12

Relevant ERP Components of Emotional Word Processing 21

Objectives and Hypotheses 29

Objective 1. 29

Objective 2. 30

Objective 3. 32

PART II. EXPERIMENTS 34

EXPERIMENT 1 35

Abstract 35

Introduction 36

Material and Methods 41

Results 46

Discussion 50

Conclusion 55

EXPERIMENT 2 57

Abstract 57

Introduction 58

Methods 63

Results 76

Discussion 80

Conclusion 85

EXPERIMENT 3 86

Abstract 86
Introduction 88
Material and Methods 93
Results 102
Discussion 108
Conclusion 114
General Discussion 116
Conclusions 123
References 125
APPENDICES 159
Appendix 1 159
Appendix 2 170
Appendix 3 172
Appendix 4 194
Appendix 5 201
Appendix 6 205
Appendix 7 212

PART I. THEORY

Introduction

A word's emotional connotation is an important component of its meaning and function in daily communication. Most psycholinguistic studies investigating emotional word processing have focused on a gross distinction between positive and negative valences rather than examining specific emotions. However, emotional words can express a variety of emotional nuances of the same valence (e.g. "vomit" and "failure"). The present thesis goes beyond the general contrast between positive and negative valence stimuli, providing more detailed evidence on how emotional connotations within the same valence affect word processing; to this aim the thesis chose disgust, one of the six basic emotions proposed by Ekman, as the emotion of interest and in some experiments established sadness, another negative emotion, as a contrast condition.

This thesis consists of three experiments. The first experiment investigated the electrophysiological signatures associated with the processing of disgust-realted words, compared to neutral words, to test a neural embodiment hypothesis. In addition, the experiment was conducted using Mandarin, a language different from Indo-European languages in a series of features such as the impoverished inflectional morphology, the abundance of monosyllabic words, and the logographic writing system. The second experiment explored the acquisition of words' connotations of disgust or sadness using an associative learning paradigm, in which facial expressions or emotional sentences were repeatedly paired with pseudowords to find out which of these materials is more efficient to induce emotional meaning in novel words. Finally, the third experiment also used an associative learning paradigm pairing pseudowords and face expressions, to examine how acquired disgusting or sadness connotations of new words differentially affect electrophysiological activity, again to test the neural embodiment of the semantics of emotions.

The Embodiment Approach to Emotions

The theory of embodiment semantics proposes that word meaning is grounded on experience and reuses the neural systems of perception, action, and emotion (Barsalou, 2008; de Vega et al., 2008; Glenberg & Kaschak, 2002; Horchak et al., 2014; Niedenthal et al., 2005; Zwaan, 2014). Previous studies have demonstrated that motor and premotor brain regions are involved in the processing of action-related words or sentences. For example, Hauk and colleagues (2004) employed functional magnetic resonance imaging (fMRI) to measure participants' brain activity while presenting them with face-, arm-, and leg-related words, which were matched for various lexical variables, in a passive reading task. Results suggested that brain areas directly adjacent to or overlapping with areas activated by actual movements of the tongue, fingers, or feet are activated when participants passively read action words referring to these body parts. Such results indicated that the meaning of action words is correlated with somatotopic activation of the motor and premotor cortex.

In addition to actions, studies on emotion processing in language also yielded a similar correlation between emotional meaning and the body. Havas and colleagues (2007) manipulated participants' facial expressions by asking them to hold a pen in the mouth by just the teeth or just by the lips, inducing indirectly a physiological smile or sad expression respectively, in three experiments to investigate the role of emotion simulation in language comprehension. In the first experiment, participants were instructed to read sentences describing pleasant and unpleasant scenarios and judge their pleasantness under one of the two pen-in-mouth conditions. In the second experiment, participants were asked to respond to sentences as either “easy” or “hard” to understand under the pen-in-mouth conditions. And finally, in experiment 3, participants kept holding the pen in their mouths and performed a lexical decision task involving neutral or associated primes and word or nonword targets. The experimental results demonstrated an emotion-sentence compatibility effect as judgment times were faster when facial posture and sentence valence were consistent (i.e., pleasant sentence with pen in teeth) than when they were inconsistent (i.e., pleasant sentence with pen in lips), yet no such effect was manifested in the lexical decision task involving emotional words. Therefore, this study suggested that the emotional systems contribute to language comprehension beyond the initial lexical access as the effect diminished in the lexical decision task involving emotional words. In an electromyographic (EMG) study carried out by Foroni and Semin (2009), two experiments were conducted to investigate whether semantic stimuli induce motor resonance in facial muscles that are involved in emotional facial expressions. EMG responses of the *zygomatic major* muscle, involved in smiling, and *corrugator supercilia* muscle, involved in frowning, were measured in the first experiment where participants were presented with concrete verbs referring to specific perceptual features of emotional expressions (e.g., to smile) and abstract adjectives referring to states associated with emotional expressions (e.g., funny). Motor resonances for the appropriate facial expression muscles to both concrete verbs and abstract adjectives were found although the intensity was higher for the former than the latter. In the next experiment, participants saw funny cartoons preceded by the words in the first experiment being presented for only 30 ms while half of the participants' facial motor resonances were inhibited using the pen-in-mouth manipulation. The task was to rate the funniness of the cartoons. This second experiment revealed that emotional words influence affective rating even when presented subliminally yet such an effect only occurs when motor resonance is possible. Taken together, this study indicated that emotion simulation occurs during language comprehension and can shape people's judgments. In the same line of research, Havas and colleagues (2010) presented participants with happy, sad, and angry sentences while their reading times were recorded; the experiment was carry out in two sessions, before and after receiving the injection of botulinum toxin-A (BTX) in their *corrugator supercilia*, as part of a cosmetic treatment, which temporarily prevents them from frowning. Results suggested that after the injection of BTX, participants' reading times for both angry and sad sentences were significantly longer than before receiving the injection, which indicates a bidirectional link between emotion expression and language.

The embodied link between emotion and language was also found by Chwilla and colleagues (2011) using electrophysiological approach. The researchers designed a mood induction procedure where two different groups of participants were shown happy and sad video clips, respectively. The effectiveness of the mood induction was measured by asking participants to rate their mood on a rating scale that -10 equals extremely sad, 0 equals neutral, and +10 equals extremely happy. After that, participants read four blocks of sentences with high- and low-cloze probability critical words while their EEG data was recorded. The clips were shown again between each block to consolidate the mood induction effect. The mood induction was successful as those who watch the happy clips scored higher than those watching the sad clips in the mood rating scale. Meanwhile, the N400 cloze effect was strongly reduced by sad mood compared with happy mood. The results further supported the embodied theory that language is grounded in the bodily states that comprise emotions. Another important finding regarding the embodied processing of emotion in language is the "approach-avoidance" effect. Mouilso and colleagues (2007) asked two groups of participants to read angry, sad, and neutral sentences along with nonsense fillers while making responses to emotional sentences by either pushing a lever away or towards their bodies. The authors found that participants' push-away responses were faster after reading angry sentences and push-towards responses were facilitated by reading sad sentences. Such a pattern suggested that emotional language processing influences emotional action tendencies, which manifests that emotional language can be embodied. Lugli and colleagues (2012) composed sentences referring to either a positively or negatively connoted object and a motion toward the self or other persons (self & other person in experiment 1 and self, positive target, e.g. friend, negative target, e.g. enemy, & neutral target, e.g. man in experiment 2) as well as non-sense filler sentences. Participants were instructed to judge whether the presented sentence makes sense by either pulling the mouse toward or away from their bodies. It was found that participants' reaction times were shorter when performing pulling-toward responses for sentences referring to positive objects. The finding clearly demonstrated that emotional valence influences bodily performance.

The studies discussed above have provided empirical evidence that semantic content is grounded in perceptual-motor and emotional processing. It may be concluded that perceiving and processing emotions recruit the perceptual, somatovisceral, and motoric systems (Niedenthal, 2007) and thus emotions will be processed simultaneously with, if not prior to, semantic content during language comprehension and activate the neural systems outside the standard language network.

The Emotion of Disgust

Ekman proposed that there are six basic emotions universally experienced in all human cultures; namely, happiness, sadness, disgust, fear, surprise, and anger, based on eight characteristics of signal, physiology, antecedent events, rapid onset, short duration, unbidden occurrence, automatic appraisal, and coherence among responses (Paul Ekman, 1992b). Among them, disgust is an emotion highly relevant to our well-being (Rozin & Fallon, 1987). The definition of disgust varies according to the focus on object or action. Darwin defined disgust as "something revolting, primarily in relation to the sense of taste, as actually perceived or vividly imagined; and secondarily to anything which causes a similar feeling, through the sense of smell, touch and even of eyesight" (Darwin, 1872). Angyal (1941) held that disgust is the aversion of the possibility of oral intaking of offensive objects. He also identified body wastes as a focus of disgust and the intensity of disgust is related to the degree of intimacy of contact. Rozin and Fallon (1987) expanded Angyal's definition by adding "The offensive objects are contaminants; that is, if they even briefly contact an acceptable food, they tend to render that food unacceptable". In addition to food and ingestion, Curtis and colleagues (2001; 2004) provided evidence that the best account for disgust is infection potential and proposed that disgust is thus evolved to protect humans from being infected. According to the above-mentioned definitions, it is likely that the properties of disgust are shaped by disease threats and infection as humans eat more animal-origin food and start living in groups, which increases the risks of parasite (Rozin et al., 2008).

This thesis focused on core disgust, which is elicited by a sense of possible oral intaking, offensiveness, or contamination (Rozin et al., 2008). Most external material stuff enters human bodies through the mouth and such entrance is generally irreversible except by vomiting (Rozin & Fallon, 1987). Rozin and colleagues (1995) provided empirical evidence that the sense of aversion of contacting offensive entities is stronger for the mouth than for other body parts by conducting surveys in participants asking them to rate the vulnerability or sensitivity of various body parts to intrusion and contamination. Regarding offensive entities, human and animal body products such as feces, vomit, urine, sweat, and blood are all aversive and disgust-inducing (Angyal, 1941; Meigs, 1978). Some animals are disgusting themselves as they resemble body products (e.g. slugs - mucus) or they are commonly in relation to rotting flesh, feces, or other human or animal wastes (e.g. cockroaches). Notably, there are certain animals eliciting both fear and disgust (e.g. snakes) and Davey and colleagues presented evidence that aversion towards these animals is more disgust- than fear-based by showing participants pictures of such disgusting and fearsome animals and asking them to rate the intensity of disgust and fear induced by these animals (Davey, 1993; Ware et al., 1994; K. Webb & Davey, 1992). Finally, contamination is universally effective in inducing disgust in entities that are originally non-disgusting. For example, American adults felt that drinks become undesirable after only briefly contacted a sterilized, dead cockroach and clothes previously worn by a disliked person were less desirable than those previously worn by a liked or neutral person, and refused to eat food shaped into a disgusting object measured by questionnaire responses (Rozin et al., 1986).

Disgust is also characterized by encouraging withdrawal and avoidance behaviors to repel the objectionable sensory input of infectious and offensive entities and such behaviors are usually motivated by sensation or imagery (Woody & Teachman, 2006). Disgust can also induce a variety of psychophysiological responses. In a study investigating the effects of specific emotion on airway changes, Ritz and colleagues (2005) showed asthmatic and healthy participants pictures of various emotions while their oscillatory resistance, respiration, and cardiac activity were measured. The researchers found that disgusting pictures elicited increased oscillatory resistance in both asthmatic and healthy participants. Stark and colleagues (2005) presented participants with 36 disgusting pictures of different intensities, each for 8 seconds, and asked them to rate the pictures on the Disgust Sensitivity Scale. During the picture presentation, participants' heart rate (HR), skin conductance response (SCR), and EMG activity of the musculus *elevator labii* were registered. Participants' disgust ratings were negatively correlated with HR and positively with SCR. More disgusting pictures elicited higher EMG responses than neutral ones, yet the EMG responses were not correlated to participants' disgust rating. Concerning disgust-related facial movements, Rozin and colleagues (1994) employed a facial expression identification design to investigate the relationship between certain facial movements and disgust-eliciting objects and scenarios. In the first experiment, the researchers asked four persons (two males and two females) to pose 12 specific facial gestures in two types: standard expressions of three basic emotions that could be confused with disgust, fear, anger, and surprise, and nine expressions of specific facial action units that were hypothesized to be related to disgust. Experimental participants were instructed to match the faces with a set of situations including negative sensory stimulation of mouth, nose, and eyes; imaginative offensive stimuli of various sensory modalities; food and nonfood prototypical disgust-inducing situations; prototypical situations for other negative emotions than disgust; and one-word emotion labels and rate their choice confidences. Among all action units, nose wrinkle, upper lip raise, and gape with tongue extension stood out from others to be closely related to disgust. In the following experiment, the researchers narrowed down to three faces showing with these three action units respectively and instructed participants to match them with 15 disgust-inducing and three anger-inducing situations. It was found that the mapping between the three action units and disgust-inducing situations remained despite certain statistical differences from experiment 1. The third experiment was then conducted to refine the results in which the three action units were perfectly demonstrated without any confounds. By doing this, a stronger mapping effect than that found in experiment 2 was yielded. Therefore, nose wrinkle, gape and tongue extrusion, and raised upper lip are the typical components of facial expressions in response to disgusting stimuli.

Researchers have also found the neural basis of disgust processing in the brain. Brain lesion studies have suggested that when asked to select emotion labels for faces, non-verbal emotional sounds, and prosodic emotional digits expressing the six basic emotions, a patient with damaged insula and putamen showed significant incompetency in identifying the emotion of disgust exclusively (Calder et al., 2000). In another case report, a patient with a lesion in the right anterior insular region suffered the feeling of disgust when seeing pictures containing curved/multicolored lines or tangles, which indicated that anterior insula lesion may have resulted in a decoupling of emotional and visceral response to complex visual stimuli and disgust perception (Cantone et al., 2019). In addition to patients with brain lesions, researchers also investigated disgust processing in obsessive-compulsive disorder (OCD) patients, whose symptomatic behaviors are associated with activation in the insula. When showed OCD-related, disgusting, and neutral pictures, patients with OCD demonstrated no heightened activity in the insula for disgusting pictures compared with healthy participants. However, their insular activity was enhanced for specific OCD-related pictures (Viol et al., 2019). There have also been numerous brain imaging studies investigating disgust processing in healthy participants. Phillips and colleagues (1997) presented participants with disgusted and fearful faces whose expression intensities were divided into mild and strong by either weakening or enhancing the facial features of the prototypical faces. The emotional faces were presented along with neutral faces, an emotional control baseline. Participants were instructed to judge the gender of each face by pressing one of two buttons with their thumbs. fMRI results suggested that while the amygdala manifested more activation for fearful faces, both mild and strong expressions of disgust activated the anterior insular cortex but not the amygdala. Wicker and colleagues (Wicker et al., 2003) moved further than Phillips and colleagues' study by introducing disgusting odorants in order to examine the brain spatial dynamics when experiencing disgust. Participants performed two visual and two olfactory experimental sessions. In the visual sessions, video clips showing individuals smelling the content of a glass were presented. The glass contained an unpleasant, pleasant, or neutral odorant and thus the individuals in the clips would react with a disgusted, pleased, or neutral facial expression. In the olfactory sessions, participants themselves were exposed to disgusting and pleasant odorants. It was found that both observing disgusted faces and feeling disgust activated the anterior insula. The activation of the anterior insula was also found when participants viewing pictures depicting contamination and mutilation (Wright et al., 2004). Pictures of contamination scenes showing poor hygiene or poisons, mutilation scenes showing human injuries and disease, fear scenes showing imminent attacks, and neutral scenes showing objects such as landscapes and household tools were presented to participants and the anterior insula responded only to contamination and mutilation but not attacks and neutral scenes. Schienle and colleagues (2017) administered 90 disgusting and 90 neutral pictures and showed them to participants in three different sessions on three consecutive days. In the first session, participants viewed 30 pictures of each emotional condition passively. In the second session, participants received a capsule for oral intake as a placebo, which was suggested to be able to reduce disgust-related symptoms, before viewing the pictures. In the third session, participants were instructed to imagine that the contents in the pictures were unreal but artificially created so that participants' picture viewing would involve a cognitive reappraisal process. After viewing each picture in each session, participants rated the intensity of disgust experienced on a 9-point scale. The researchers found that while the placebo and reappraisal manipulations reduced the experienced disgust intensity effectively, the activation of the insula and dorsolateral prefrontal cortex was reduced in the placebo condition but enhanced in the reappraisal condition.

In conclusion, the above-mentioned empirical findings in both patients and healthy participants indicated that the insula is likely to be the brain structure responsible for processing disgust of various modalities.

Learning Words' Emotional Meanings

Investigating which is the more efficient approach for acquiring the connotation of disgust for new words and how such acquisition modulates neural dynamics are important research objectives of this thesis. Consequently, faces and sentences were selected in this investigation as candidate materials to examine the acquisition of disgusting connotations.

Faces

Facial expressions have been considered as effective communication channels (Darwin, 1872) and especially, an essential and common component for conveying and perceiving emotions (Paul Ekman, 1992a, 1993). For humans, the initial acquisition in life of emotional signals occurs when children recognize the facial expressions of their caregivers (Denham, 1998; Caroll E Izard, 1971). Later on, the association of faces and language occurs. For instance, Markham & Adams (1992) carried out an experiment including four tasks on 24 children aged 4, 6, and 8 years. In the discrimination task, the researchers showed the children a series of photos of persons expressing various emotions and gave them emotion labels and corresponding relevant typical situations.

The children were instructed to select the photo that matches the given emotion label and situation. In the matching discrimination task, the researchers described the emotion felt by a person and then showed the children four photos of persons demonstrating different emotions, among which they have to choose the one expressing the same emotion as described. In the forced choice labeling task, the children were required to choose the correct emotion label for each photo shown. Finally, the free labeling task required the children to respond to each photo shown with either single words or short phrases when asked "How was this person feeling when their photo was taken". Results across the four tasks suggested that response accuracy increased with age and the children's performances were task-dependent. Such an age-driven developmental recognition of emotions was discovered with larger sample sizes and broader age variations. Vicari and colleagues (2000) recruited 120 school-aged children who were 5 – 10 years old and assigned them to an emotion matching task, in which the children were asked to choose matching photos for target expressions from four alternatives, an emotion memory task, in which the children viewed the photos for 5 seconds and then selected photos expressing the same emotions from alternatives, an emotion recognition task, in which the children were instructed to read short stories expressing various emotions and select photos that match the emotion conveyed by the stories, and an emotion labeling task, in which the children viewed the photos and responded with emotion labels. The researchers discovered an increase in response accuracy with ages by analyzing the children's performances. The results of the two children-based studies suggested that the acquisition of emotion labels for concrete emotions proceeds with age as children's language proficiencies improve.

Concerning words' emotional meanings, a lot of empirical evidence has suggested that emotional words are tightly associated with facial expressions in one's semantic memory. The Stroop task was commonly used to examine the interaction between emotional words and faces. Stenberg and colleagues (1998) set up three experiments in which happy, angry, and neutral faces; happy, sad, and neutral faces, and sad, angry, disgust, happy, and neutral faces were employed. respectively, as primes and positive and negative emotional words as targets. The task was to judge the emotionality of the words Results of all three experiments demonstrated that negative words generally took longer to process than positive words and the processing of negative words was facilitated by negative face primes and inhibited by positive face primes compared with positive words. Beall and Herbert (2008) prepared a series of happy, sad, and angry faces and positive and negative words for two experiments. In the first experiment, happy and sad faces were used along with the emotional words to construct two experimental conditions. In both conditions, the faces and words were presented together but in the first condition, participants were instructed to judge the valence of the words while ignoring the faces and in the second condition it was the other way around. In the second experiment, the more aggressive and threatening angry faces were introduced to replace sad faces to further investigate the Stroop-like interference effect between faces and words. Generally, the interference effect was found in both conditions. Specifically, the effect was more prominent during valence judgments of words than faces and angry faces showed a larger interference effect than sad faces. There was no significant difference between angry faces and happy faces regarding the interference effect, which indicated that emotions in faces were processed faster than those in words. Using the similar design, Kar and colleagues (2018) investigated the proactive and reactive control effects in the face-word Stroop task. The proactive control effect was defined as “the reduction of Stroop interference (difference between incongruent and congruent trials) as a function of previous trial emotion and previous trial congruence" whereas the reactive control effect "the reduction in Stroop interference as a function of current trial emotion and previous trial congruence" The researchers used also happy, sad, and angry faces in two experiments but participants were only asked to respond to the valence of the faces. Moreover, instead of positive and negative words, only the emotion labels (happy, sad, and angry) corresponding to the three types of faces were adopted. Regarding the proactive control effect, sadness, and anger in previous trials exerted a greater influence on proactive control than happiness. For the reactive control effect, sad faces in previous trials generated more reduction in the Stroop interference for happy faces in current trials and angry faces in current trials were more adaptive than happy faces. It was concluded that the emotional valence of task-relevant stimuli influences both proactive and reactive control and the adjustive behaviors reflected when encountering conflicts are crucial for emotion regulation.

In addition to the behavioral approach, there have also been studies using electrophysiological techniques to examine the Stroop interference effect between faces and emotional words. For example, Baggott and colleagues (2011) selected angry, sad, fearful, and neutral faces and emotional words (e.g., "furious" for anger, "depressed" for sadness, "afraid" for fear) as experimental stimuli in an emotion-congruency judgment task. A congruency effect was found in behavioral results as participants were faster in judging congruent face-word pairs. ERP data analyses demonstrated enhanced N170 amplitudes for incongruent trials compared to congruent trials, indicating early processing of emotional information conveyed by both faces and words. The face-word Stroop effect was also tested in bilinguals. The Stroop interference was more prominent for Chinese-English bilinguals in their first than second language when they judged whether the face presented expresses happiness or fear while ignoring the emotional word presented simultaneously, indicating stronger emotionality for participants' first language (Fan et al., 2018). Furthermore, participants' ERP data showed that a negative-going wave between 350 – 550 ms after stimuli onset appeared to be larger for incongruent than congruent first language trials. First language incongruent trials elicited a more pronounced negative amplitude between 230 – 330 ms after stimuli onset than second language incongruent trials. The enlarged orthographic decoding negativity between 230 – 330 ms and the conflict processing negativity between 350 – 550 ms provided electrophysiological evidence for the emotionality enhancement in participants' first language (Fan et al., 2016). Such a conclusion was also drawn from EMG studies on bilinguals. Baumeister and colleagues (2017) selected 20 happy words, 20 angry words, and 40 neutral words in Spanish and English and recruited Spanish-English bilinguals to perform an emotion-association judgment task in which they were instructed to identify whether the present word is associated with emotion or not while their EMG signals were recorded. The bilinguals then completed a surprise memory task 24 hours later, which included words in the previous session and a set of new words. The bilinguals then had to indicate whether the word presented is from the previous session or new. A memory advantage was manifested in emotional words compared with neutral words in the first language but not the second language. Regarding EMG results, facial motor resonance and skin conductance responses to emotional words in the first language were marginally enhanced compared with the second language. It is worth noting that although the EMG responses to emotional words were reduced in the second language compared to the first language, they were not completely absent, indicating that the association between facial expressions and emotional words exists, at least partially, even in people's second language that is acquired later in life.

The functional role of faces as emotion acquisition materials have been tested in both healthy participants and patients. Walther (2002) designed five experiments to investigate the mechanism of attitude formation by pairing liked or disliked persons' faces with previously neutral persons' faces. The five experiments investigated the attitude spread effect, which in this study means a liked or disliked face may affect not only the evaluation of the neutral face but also other faces related to the liked or disliked face, with various paradigms including evaluative conditioning, aversive evaluative conditioning, and second-order conditioning. Results of the different experiments in the study suggested that the face pairs indeed elicited the spreading attitude effect that was strong enough as to resist extinction and facilitate second-order conditioning and happened regardless of cognitive resources availability. Blessing and colleagues (2013) showed dementia patients and a group of healthy participants a set of neutral unfamiliar faces paired with liked, disliked, and neutral faces. The patients and healthy participants were both instructed to rate the valence of all faces before and after stimuli presentations. Compared with healthy participants, the patients changed their valence ratings of the unfamiliar faces based on whether they were presented with liked or disliked faces. In addition, the patients rated unfamiliar faces as more positive when they were presented with neutral faces, which was explained by the authors as an exposure effect. In conclusion, the results of the above-mentioned two studies on both healthy participants and dementia patients have shown that emotion-laden faces can effectively change the perceived valence of neutral faces. Whether such an emotional transference exists when faces are paired with unfamiliar written words remains unclear. The current thesis aimed at filling this research gap by introducing disgusted and sad facial expressions as potential emotion acquisition materials for new words.

Linguistic Materials

Linguistic materials such as words and sentences are common resources for acquiring meanings for new words. Statistical theories of meaning, notably the latent semantic analysis theory (LSA) demonstrated that word co-occurrence data obtained from big corpora of representative texts, allow to compute a number of dimensions in a vectorial space in which words are represented as vectors; moreover, some mathematical relations (cosines) accurately reflect semantic relations among them (Landauer & Dumais, 1997). According to the ASL theory, these facts strongly suggests that word meaning arises from linguistic contexts. The functional role of linguistic contexts in meaning acquisition has been widely investigated in laboratory settings. In an eye movement study carried out by Chaffin and colleagues (2001), sentences containing target words differing in familiarity (high, low, and novel) and words related to target words were combined to build sentences that were either informative or neutral about the meaning of the target words. Participants were instructed to read the sentences and answer random yes or no comprehension questions while their eye movements were monitored. It was found that both the familiarity of the target word and the informativeness of the sentence influenced participants' reading time, and that additional time was spent on the word related to the target only when the context was neutral. Such results suggested that readers were able to detect the relevant parts of the sentences for understanding novel words. Frishkoff and colleagues (2010) examined the effect of meaning acquisition with linguistic contexts by measuring participants' ERP data before and after learning. The researchers prepared familiar words and new words as well as sentential contexts that are either semantically constraining or uninformative to the new words. The experiment was conducted in two separate sessions. In the first session, participants read the contexts containing the new words and after each sentence, the new word was presented in isolation and participants were instructed to provide a corresponding synonym. The second session took place two days after the first session and aimed to examine the delayed learning effect. Reduced negativity in the left temporal sites around 300 ms after stimuli onset was obtained in the ERP data of the first session for new words learned in high-constraint contexts than those in low-constraint contexts. Yet, both types of new words elicited a stronger medial frontal negativity around 350 ms than familiar words. The delayed learning effect was manifested in a late left parietal positivity (600 ms) instead of the left temporal negativity. An additional semantic priming test was carried out in the second session to further probe into the learning effect in which the learned new words, familiar words, and unlearned new words served as primes and semantically related and unrelated familiar words were targets. Participants were asked to decide whether the prime and the target were semantically related or not. The classical N400 effect was stronger for familiar words and new words learned in high-constraint contexts while weaker for new words learned in low-constraint contexts. Unlearned new words elicited no N400 effect at all. The results across these various tasks suggested that the linguistic contexts and the following synonym generation were highly effective for meaning acquisition.

Besides general meaning acquisition, there has also been empirical evidence suggesting that pairing emotional words with neutral words can effectively change the valence rating of neutral words. Back in the 1950s, Staats & Staats (1957) conducted experiments pairing meaningless syllable with emotional word pairs and testing memory and valence for the syllables. Results suggested that the originally meaningless syllables acquired emotional valence through the pairing with emotional words. Such an effect was also found occurring in the absence of contingency-awareness. When participants viewed a series of neutral words presented for 2500 ms followed by either a positive or negative word presented only for less than 30 ms, they were not even aware of the presentation of emotional words during the experiment. However, the neutral words were still rated more positive when followed by a positive word and more negative when followed by a negative word (de Houwer et al., 1994). In a follow-up study (de Houwer et al., 1997), the researchers replaced the neutral words with meaningless pseudowords and reduced the number of emotional words to one extremely positive and one extremely negative, reporting similar changes in valence ratings of the pseudowords. Next, the number of presentations of pseudoword – emotional word pairs were doubled and the pairings between pseudowords and emotional words were fixed rather than randomized. In addition, participants were asked whether they were aware of the presentation of emotional words during the experiment. Results suggested that emotion acquisition for pseudowords occurred even for participants who did not aware of the emotional word presentation. Finally, the researchers set up two experimental conditions in which the pseudoword – emotional word pairs were presented to participants either two times or four times. However, the emotion acquisition effect was not significant neither when the word pairs were presented two times nor four times. Nevertheless, the meta-analysis conducted by the authors of the results of different experiments in the study yielded a relatively minor yet statistically reliable emotion acquisition effect.

Using sentences as materials of emotion acquisition for neutral stimuli was rare in previous studies. One example was Junghofer and colleague’s work (2017). Sixty sentences describing either neutral occupations or aversive criminal activities were constructed, and 60 neutral faces were selected from the KDEF database. Participants were instructed to rate the valence and arousal of the faces before and after the magnetoencephalography (MEG) recording session and complete a face – sentence matching task at the end of the experiment. During the MEG recording session, there was a learning phase where the faces were presented with either sentences describing neutral occupations or aversive criminal activities auditorily. In addition, the faces were presented alone to participants before and after the learning phase. The learning phase significantly influenced participants' ratings of the faces and MEG activity. Faces paired with criminal activities were rated more arousing and negative than those paired with neutral occupations and elicited stronger magnetic fields in the left visual cortex between 220 – 320 ms after stimuli onset, and thus proved that it is possible for neutral stimuli to acquire emotional connotations from sentences conveying emotional information. Regarding neutral verbal stimuli, in real life, when we look up an unfamiliar word in the dictionary or learn a word from another language, it is common that we resort to sentences, which provide more detailed and specific information than single words, to understand its meaning, especially the more complex emotional connotation. There has been no study using sentences for acquiring emotional connotations for new words to date and thus, whether sentences are effective materials for new words to acquire disgusting connotations was investigated in this thesis.

Relevant ERP Components of Emotional Word Processing

The ERP technique measures brain electrophysiological activity with electrodes placed on the scalp and applies subsequent data processing time-locked to the target stimuli, to obtain evoked activity. It shows high temporal resolution and thus is useful for investigating the time-course of cognitive functions and processes. The relatively low spatial resolution of the ERP technique can be complemented by using caps with many electrodes (i.e., 64 or 128) to acquire more comprehensive data so that the neural generators of the recorded ERP components can be computed using source estimation techniques. In this way, a complete picture of the spatiotemporal dynamics of disgust processing in written words can be yielded by measuring ERP components and their likely brain sources.

According to previous studies, a series of ERP components have been repeatedly reported to be related to emotion processing in verbal stimuli. In the early time window, the early posterior negativity (EPN) is one of the most representative components in this regard. The EPN is a negative-going waveform appearing 200 – 300 ms after stimuli onset and is located in posterior and occipital electrodes. Larger EPN amplitudes for emotional than neutral words were found in various experimental paradigms. Kissler and colleagues (2007) designed a silent reading and free-recall task in which pleasant, unpleasant, and neutral nouns were shown to participants in a rapid serial visual presentation (RSVP) format differing in fast and slow rates. Pleasant and unpleasant words were better memorized than neutral words and elicited larger EPN amplitudes and such effects were more pronounced for the fast presentation rate. Using a similar design, Herbert and colleagues (2008) investigated the differences among pleasant, unpleasant, and neutral adjectives. Results suggested that pleasant adjectives were remembered better than neutral adjectives and pleasant and unpleasant adjectives elicited larger EPN in the fast presentation rate. Moreover, the researchers looked into the hemisphere distribution of EPN and found it to be more pronounced for negative adjectives than neutral adjectives in the left hemisphere. Finally, nouns and adjectives were mixed and presented for a fixed period of time in a silent reading and free-recall task and a word counting task. Once again, the EPN was enhanced by emotional words compared with neutral words (Kissler et al., 2009). The emotional EPN effect is also commonly found in the lexical decision paradigm. Scott and colleagues (2009) selected positive, negative, and neutral words of high and low frequencies and designed a lexical decision task with an additional set of pronounceable pseudowords. The EPN reflected not only an emotion but also a frequency effect. Positive words and negative words elicited larger EPN than neutral words and such effect was significant only for words of high frequencies. Palazova and colleagues (2011) designed a lexical decision task with adjectives, verbs, and nouns of positive, negative, and neutral valences and pseudowords. Half of the words were high, and the other half were low in frequency. The EPN effect varied based on different word categories. Positive and negative nouns elicited larger EPN than neutral nouns, positive adjectives elicited larger EPN than negative adjectives, and positive verbs elicited larger EPN than neutral verbs. The different EPN amplitudes between emotional words were also reported in nouns in a lexical decision task using RSVP; in this case, larger EPN was found for positive nouns than negative and neutral nouns. It was worth noting that in the same study when distractors were non-recognizable stimuli instead of pseudowords, the emotional EPN effect diminished, which indicated that such an effect requires a certain level of post-perceptual processing as the task only requires participants to identify words from non-recognizable distractors, which are obviously different (Hinojosa et al., 2010). Moreover, the emotional EPN effect was proved to be task-independent. For example, when pleasant, unpleasant, and neutral nouns were paired with possessive pronoun “my” or “his”, which indicated different self-referentiality, larger EPN was elicited by pleasant and unpleasant words both in self-reference and other-reference conditions (Herbert et al., 2011). Concluding the empirical evidence, the EPN is considered as an indicator of the amount of attentional resources allocated to processing selective emotional stimuli in the early stage (Junghofer et al., 2001; Schupp, Junghöfer, Öhman, et al., 2004; Schupp, Junghöfer, Weike, et al., 2004). There have been controversies, however, on the lateral distribution of the component. Junghofer and colleagues (2001) prepared pictures of high and low arousals and presented them to participants either 10 frames (the fast condition) or 6 frames (the very fast condition). Enhanced EPN amplitudes were found for highly arousing pictures in both conditions and the effect was more pronounced in the right hemisphere comparing with the left. Using the RSVP paradigm, Schupp and colleagues (2006) selected pictures depicting erotic couples, mutilations, and neutral scenes as stimuli. Once again, results suggested that larger EPN was elicited by emotional pictures compared with neutral ones and the effect was more robust in the right hemisphere. However, in the studies investigating the visual processing of emotional nouns and adjectives described above (Herbert et al., 2008; Kissler et al., 2007), a left-hemisphere advantage for the EPN effect was manifested.

One of the main research objectives of this thesis was to investigate disgust processing in Mandarin, which is different from the Alphabetic languages used in the above-reviewed studies. One commonly found early ERP component in studies involving Mandarin is the P2 (or P200). It is a positive-going waveform that peaks around 200 ms after stimuli onset with a distribution in the centro-frontal electrodes. It was reported to be enhanced by words that are phonologically related to previous priming words in word pairs compared with those that are unrelated in a homophone judgment task (Zhang et al., 2009). Kong and colleagues conducted two experiments to investigate the relationship between P2 and phonological (2010) and orthographic (2012) processing. In the phonology study, participants performed a semantic judgment task on word pairs. The stimuli consisted of filler pairs, which were semantically related, and target pairs, which were semantically unrelated and further divided into homophonic, rhyme, and phonologically unrelated. Results suggested that both homophonic and rhyme pairs elicited larger P2 amplitudes, which indicated that P2 was sensitive to lexical phonology at both the syllabic and sub-syllabic levels. As for the orthography study, the same semantic judgment task was adopted, and the stimuli were semantically related filler word pairs and orthographically related but semantically and phonologically unrelated target word pairs. Results demonstrated reduced P2 for orthographically related pairs, suggesting that P2 is sensitive to orthographic similarity. However, in addition to be an orthographic signature, the P2 component was also reported to be sensitive to the processing of emotional words. Herbert and colleagues (2006) showed participants pleasant, unpleasant, and neutral adjectives and instructed them to perform an emotional evaluation task. It was found that both pleasant and unpleasant words elicited larger P2 amplitudes than neutral words. Kanske and Kotz (2007) designed a lexical decision task in which positive, negative, and neutral nouns that varied in concreteness and length and pronounceable pseudowords were included. The P2 was reported to be larger for positive words than neutral words. Ding and colleagues (2016) examined the influence of emotional words on the semantic integration of following neutral nouns during sentence comprehension using Mandarin stimuli. A sentence structure of introductory context followed by a critical verb and noun and then other information was established and thus creating four experimental conditions: negative verb – noun congruent, negative verb – noun incongruent, neutral verb – noun congruent, neutral verb – noun incongruent. Participants were instructed to read the sentences carefully and complete a comprehension test after the sentence presentation. The P2 component in such a design was enhanced by negative verbs compared with neutral verbs. In conclusion, the results of the literature reviewed above indicated that the P2 component was similar to the EPN component when it comes to emotional words processing in Mandarin, although both components differ in polarity and scalp distribution.

Following the early components of EPN and P2, the N400 and late positive complex (LPC) are usually found in emotional word processing. The N400 is a negative-going deflection that peaks around 400 ms after stimuli onset with a typical distribution in centro-parietal electrodes. The N400 was commonly reported to be an indicator of lexical and semantic processing (Kutas & Federmeier, 2000; Lau et al., 2008). But empirical evidence has suggested that it is also sensitive to emotional variables. Kanske and Kotz (2007) reported larger N400 manifested for neutral words than positive and negative words and concrete words than abstract words in a lexical decision task. While in the study focusing on the brain dynamics of emotional adjective processing carried out by Herbert and colleagues (2008), unpleasant adjectives elicited larger N400 amplitudes than pleasant adjectives and the overall amplitude was reduced by repetitions. Sass and colleagues (2010) reported enhanced N400 amplitudes for neutral words compared with arousing words in an emotional Stroop task in which pleasant, threat, and neutral words were presented in four different colors. Similar results were obtained by Gootjes and colleagues (2011). The researchers employed a similar emotional Stroop task in which negative and neutral words were presented in four different colors. Participants rated the valence and arousal for half of the words prior to the ERP recording so that an exposure effect could be examined. Results suggested that the N400 was enhanced by neutral words compared with negative words and new words compared with exposed words. It has been argued that the reduced N400 for emotional words reflects facilitated lexical or semantic processing (Citron, 2012).

The LPC is a positive-going waveform that has been found in numerous studies in relation to emotions. Its main distribution is in the centro-parietal sites and usually begins around 400 – 500 ms after stimuli onset and lasts for several hundred milliseconds. Similar to the EPN component, the LPC is usually enlarged by emotional words compared to neutral words (Hinojosa et al., 2010; Kanske & Kotz, 2007; Schacht & Sommer, 2009). Moreover, the LPC component often responded differently to positive and negative words. In Herbert and colleagues' studies that investigated emotional and neutral adjectives, positive words elicited larger LPC than negative words (2006, 2008). Such a positive preference was also reported by Kissler and colleagues (2009) as positive words elicited larger LPC than negative words in the silent reading task. Meanwhile, a reversed pattern was shown in numerous studies as well. Among the literature reviewed above, Gootjes and colleagues (2011) and Kanske and Kotz (2007) both reported an enhanced LPC for negative words compared with positive words. Finally, several studies also suggested that larger amplitudes of LPC were elicited by neutral words than emotional words. In a task requiring participants to identify words, including positive, negative, relaxing, and neutral words, among nonsense stimuli, neutral words elicited larger LPC than positive, negative, and relaxing words (Hinojosa et al., 2009). The more robust LPC for neutral words was reported by Citron and colleagues (2011) in their study employing a lexical decision task. Moreover, the LPC component was demonstrated to be manipulated by self-referentiality. In a series of studies carried out by Herbert and colleagues (2011a, 2011b), self-referenced emotional words, especially positive words, elicited larger LPC than other- or no-referenced emotional words. Taken together, the LPC component indicates more controlled, explicit, and deep processing of emotional information carried in words and thus demonstrates more refined differences between positive and negative valences compared with the EPN component. Moreover, the mixed patterns regarding the differences between emotional words and emotional words and neutral words suggested that the LPC component is more task- and stimuli-dependent.

By the time the thesis was composed, the paper introducing Experiment 1 was under journal review. The paper describing Experiment 2 has been accepted by a scientific journal and was ready for publication. Regarding Experiment 3, a paper has been written based on the results and was ready for submission. The latest versions of all three papers were presented in the thesis.

Objectives and Hypotheses

OBJECTIVE 1. To verify whether the processing of disgusting connotations in Mandarin words involves neural embodiment, and to what extent the neural signatures match those found in Indo-European languages.

To this aim, Experiment 1 was conducted using a Go/NoGo semantic categorization task. Previously, Ponz and colleagues (2014) adopted the same design to investigate the spatiotemporal brain dynamics of disgust processing in French words. The researchers prepared 35 disgust-related words and 35 neutral words as experimental stimuli and 24 vehicle names as fillers. During the experiment, the two types of words were presented along with the fillers. Participants were instructed to respond to only the vehicle names and their ERP data were recorded. Results suggested that disgust-related words elicited larger EPN, N400, and LPC than neutral words, and source localization suggested that disgust-related words generated higher current density than neutral words in the left insula, right middle temporal gyrus, and right superior temporal gyrus during the N400 time window. The more robust activation of the insula during the N400 time window suggested that the processing of disgust-related French words activated neural systems more than those involved in language processing and in this case, the neural locus of processing disgusting information of various modalities. In the first experiment of this thesis, the same experimental design as in Ponz et al. (2014) was employed but the stimuli were in Mandarin and the number of trials was increased significantly to improve the statistical power.

The hypotheses of the experiment are,

1. Disgust-related Mandarin words will elicit larger P2 than neutral Mandarin words.

2. Disgust-related Mandarin words will elicit larger LPC than neutral Mandarin words.

3. Regarding the N400 component, disgust-related words were predicted eliciting more reduced amplitudes than neutral words, since the emotional information would facilitate lexical and semantic processing.

4. The insula and other emotion processing-related brain structures are expected to be more active during the processing of disgust-related words.

OBJECTIVE 2. To examine the effectiveness of two associative contexts, faces and sentences, for acquiring disgusting and sad connotations for new words.

The second experiment of the thesis selected face expressions and emotional sentences as associative contexts to induce emotional connotations in novel words, departing from most previous studies that generally use pictures as contexts for the acquisition of words' emotional meaning (Fritsch & Kuchinke, 2013; Hofmann et al., 2009; Kuchinke et al., 2015). The two learning contexts used here, presumably differ in the cognitive and neural mechanisms involved. Whereas face expressions are primary biological signals of emotions which could be automatically interpreted, linguistic contexts provide a more indirect and cognitive route for learning. In order to yield more refined and accurate results, sadness, another negative basic emotion was introduced as an emotional control baseline to better demonstrate the unique features of acquired disgusting connotation, avoiding a confounding with pure valence effects. Sadness was chosen for several reasons. First of all, compared to disgust that is usually urgently induced by external aversive stimuli, sadness is more passive, internal, and psychological (Kreibig et al., 2007; Mikulincer & Florian, 1997). It is different from other negative basic emotions such as anger and fear, which are distinctive and easy to identify, but are also commonly induced by external threatening stimuli (Spielberger & Reheiser, 2010) as disgust. Sadness is more socially involved as it occurs when facing the loss of valuable objectives or significant others (Lench et al., 2011) and social rejection (Izard & Buechler, 1980). Secondly, a unique set of facial movements associated with sadness including lowered mouth corners and raised inner portion of the brows were reported in previous studies (Ekman et al., 2002). During the experiment, Spanish participants were divided into two groups to engage in a training session in which pronounceable pseudowords were paired with emotional facial expressions and with emotional sentences, respectively, to induce disgusting, sad, and neutral connotations in the pseudowords. Next, two memory tests probing into participants' learning of specific face/sentence – pseudoword pairs followed. Most importantly, after the training session there were two generalization tests in which the participants judged whether the learned new words applied to new faces/sentences stimuli expressing disgust, sadness or neutrality.

The hypotheses of the experiment are,

1. Faces will be more effective than sentences as contextual clues for the acquisition of emotional connotations of new words, as they are straightforward biological signals and also are socially engaging.

2. Sentences are comparable to faces regarding the acquisition of sadness as they describe more detailed social scenarios, which may facilitate the endogenous generation of sadness.

OBJECTIVE 3. To investigate how the acquired disgusting and sad connotations of new words affect the brain dynamics of word processing, and whether the neural embodiment hypothesis is confirmed for these new words.

This objective moves beyond previous studies that only focused on the influence of acquired positive or negative valences on word processing (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015). In the third experiment, Spanish participants first completed a training session in which pronounceable pseudowords were paired with faces expressing disgust, sadness, and neutrality, and then they attended the ERP recording session on the following day. During the ERP recording session, the Go/NoGo paradigm of Experiment 1 was employed, but in this case including the three types of learned pseudowords (disgusting, sad, and neutral), a set of non-learned pseudowords, a set of real words, and a set of vehicle names. The participants were instructed to only respond to vehicle names, by pressing a button and refrain from respond otherwise. The ERPs waveform were analyzed for the novel words (learned pseudowords), and the sources for the significant ERP effects, which may differ for disgust (Phillips et al. 1997; Ponz et al. 2014; Wicker et al., 2003; Wright et al., 2004) and for sadness (Niida & Mimura, 2017; Ramirez-Mahaluf et al., 2018; Webb et al., 2018), were also estimated.

The hypotheses are,

1. Disgusting new words will elicit the largest EPN compared to the other two types of new words because of the alerting nature of disgust.

2. In the late time window, neutral pseudowords will elicit the largest LPC as they lack emotional features and thus are vulnerable to the interferences from new pseudowords and real words.

3. On the other hand, disgusting pseudowords are expected to elicit the smallest LPC given the salient emotional connotations they carry.

4. As for source localization, more robust activation in the insula is expected to be found for processing disgusting pseudowords.

5. The processing of sad pseudowords is predicted to be associated with higher current density in the anterior cingulate cortex as reported in previous studies.

PART II. EXPERIMENTS

EXPERIMENT 1[1]

Embodied Processing of Disgust in Mandarin Words: An ERP Study

Abstract: The embodiment theory of linguistic meaning posits that comprehension reuses the sensory-motor systems and their neural networks. The present study aims to verify the embodiment theory by investigating the spatiotemporal brain dynamics of processing disgust-related words in Mandarin. These words were chosen because disgust is a basic emotion (e.g., it recruits neural resources in the insula) that has received little attention in neurolinguistics. The participants were required to read disgust-related and neutral words with instructions to perform a semantic categorization task while their EEG data were recorded. The results revealed that disgust-related words elicited larger amplitudes in the P2 and LPC components of the ERP and reduced the N400 amplitudes compared to neutral words. The source localization for the effects obtained in the P2 time window showed activations of the insula and other sensory and emotion-related brain structures. These results demonstrated the brain dynamics of Mandarin-speaking Chinese participants during emotion processing in words and clearly supported the theory of embodiment semantics.

Keywords: emotion; disgust-related words; Mandarin; embodiment; ERPs

[1] Experiment 1 has been accepted for publication in the *Journal of Neurolinguistics*. It is currently in press.

Introduction

Disgust is one of the basic emotions (Ekman, 1992) induced by aversive stimuli (Rozin et al., 2000). Stimuli inducing disgust usually come with the threat of contamination or disease, and feeling disgusted encourages withdrawal behaviors (Woody & Teachman, 2006). In most languages, a rich vocabulary is associated with a variety of emotions, including disgust. The neural response to disgust-related words has been relatively neglected by researchers, and is virtually absent in research involving the Mandarin Chinese language. This paper contributes to filling this gap by using the event-related potentials (ERPs) technique to study how Mandarin speakers process disgust-related words.

The amodal theory and the embodiment theory are two classical theories of comprehending lexical meaning. The amodal theory proposes that word meaning is achieved using only abstract, arbitrary mental symbols without activating the sensory-motor systems (Bobrow & Winograd, 1977; Charniak, 1978; Griffiths & Steyvers, 2004; Landauer & Dumais, 1997; Lund & Burgess, 1996). Therefore, according to the amodal theory, brain structures functionally associated with emotional processing are not immediately activated when reading emotional words, or they are activated in a late post-lexical access stage. The theory of embodiment semantics, for its part, posits that meaning is grounded in the body and reuses the neural mechanisms of perception, action, and emotion (de Vega et al., 2008; Horchak et al., 2014). For instance, a number of studies demonstrate that motor and premotor regions in the brain are activated during the processing of action-related words or sentences (Gallese, 2008; Hauk et al., 2004; for review, see Wang et al., 2019). Moreover, according to the embodiment theory, the processing of emotion-related words triggers activations in the brain regions involved in the processing of emotional information.

In this study we will test, by means of the event-related potentials (ERPs) technique, whether disgust-related words induce modulation of certain neural markers of the disgust emotion. If so, the result would demonstrate that disgust-related words are grounded on the corresponding emotion, supporting the theory of embodiment semantics. The ERP technique is an ideal tool for exploring the temporal dynamics of emotional word processing. Previous studies have provided evidence that both early and late ERP components are sensitive to the emotional features of words (Herbert et al., 2008; Kanske & Kotz, 2007; Kissler et al., 2007, 2009; Yi et al., 2015; Zhang et al., 2014). The early ERP components, include the P1-N1, which are sensitive to the interaction between word frequency and emotion (Hofmann et al., 2009; Scott et al., 2009), the P2-N2, which respond to emotional information of the stimuli (Herbert et al., 2006; Sass et al., 2010), and the EPN (early posterior negativity), which is a task-independent component usually enhanced by emotional stimuli (Herbert et al., 2008; Kissler et al., 2007, 2009); these early components were considered to reflect visual attention to the emotional content of words in early perceptual processing. For later time windows, the N400 and the LPC were commonly found during emotion word processing. The N400 is an indicator of lexical access and lexico-semantic integration and is generally larger for neutral words than emotional words, reflecting a facilitation effect of salient emotional content on lexical and semantic processing (Herbert et al., 2008; Kanske & Kotz, 2007; Ponz et al., 2014). One exception is Ponz et al.'s study (2014), which reported enhanced N400 amplitudes for disgust-related words compared to neutral words and the authors ascribed the unusual pattern to their experimental design that required participants to inhibit semantic processing over emotional words. The LPC component indicates a deeper comprehension and prolonged evaluation of the emotional content of stimuli and is therefore generally enhanced by emotional stimuli

(Carretié et al., 2001; Herbert et al., 2006; Palazova et al., 2011).

Disgust is a negative emotion induced by aversive stimuli threatening contamination or disease (Rozin et al., 2000) and is one of the six basic emotions proposed by Ekman (1992). Given the fact that stimuli inducing disgust encourage withdrawal, disgust protects us against noxious substances that may harm us or reduce our well-being (Rozin & Fallon, 1987). Brain lesion studies (Calder et al., 2000) and brain imaging studies of healthy participants (Phillips et al., 1997; Wicker et al., 2003; Wright et al., 2004) demonstrated that the anterior insula is likely to be a main neural structure involved in processing disgust information across various modalities. Other brain structures, such as the amygdala as well as the anterior and posterior cingulate gyri, were also reported as being involved in the processing of disgust (Phillips et al., 1997; Phillips et al., 2004).

In spite of the relevance of disgust as a basic human emotion, the study of the processing of disgust-related words has received little attention. Most studies in the field only conducted a gross contrast between emotional and neutral stimuli instead of focusing on investigating specific emotional categories (e.g., Fritsch & Kuchinke, 2013) while the current ERP research aimed to study the specific brain responses to disgust-related words. As stated above, disgust is usually triggered by external aversive stimuli so that disgust-related words, which refer directly to concrete disgusting objects, actions, or concepts, can serve well to induce the corresponding emotion whereas other negative emotions such as anger and fear and the only positive emotion among the six, happiness, were more effectively induced by pictures, real-life experiences, or videos rather than sign words (Ferrer et al., 2015; Yan & Dillard, 2010) To the best of our knowledge, only one ERP study has been performed on this subject with French disgust-related words as stimuli (Ponz et al., 2014). Ponz et al. recruited 21 healthy

French participants for surface EEG recording and two patients with epilepsy for intracranial EEG recording. The researchers found enhanced EPN, N400, and LPC components by disgust-related words compared to neutral words, and the source estimation for the N400 effect was the left anterior insula among healthy participants. These results were corroborated with higher accuracy, recording EEG with intracranial electrodes in two epileptic patients. Overall, the results confirmed a neural embodiment of disgust-related words, indicated by the brain temporal dynamics and the activation of brain structures beyond the language system induced by such words. French is an Indo-European language with alphabetic writing, and it remains untested whether the processing of disgust-related words also recruits the same neural mechanisms in a language such as Mandarin Chinese, which differs from Indo-European languages in several features. For instance, Mandarin has an impoverished inflectional morphology, abundance of monosyllabic words, and a logographic writing system. There is empirical evidence that supports that these features induce differential brain processes in Mandarin speakers. For example, Valaki et al. (2004) found that the neurophysiological activity in temporal and temporoparietal brain areas of Mandarin Chinese speakers differed from that of Indo-European language speakers in a spoken-word recognition task. Regarding the emotional dimension of language, it has been reported that terms denoting external and internal body parts constitute a large proportion of conventional expressions referring to emotions and emotional experiences in Chinese (Yu, 2002). Such metaphorical expressions have bodily and psychological bases. Cross-cultural studies also suggested that Chinese and English-speaking Americans differ in the ways they express emotions and describe emotional experiences. For example, Chinese patients tended to use bodily rather than psychological terms to describe their depression symptoms compared to American patients (Kleinman &

Kleinman, 1985). Some scholars proposed that in Chinese culture, psychological and physical states are considered to be tightly connected and, therefore, Chinese speakers tend to use somatic terms when expressing emotions or describing emotional events more often than English speakers (Kleinman et al., 1986; Ots, 1990). Other researchers suggested that the reason for such lexical biases is that somatic words and emotional words are more similar in Chinese logographic orthography than in alphabetic languages (Tung, 1994). Tsai and colleagues (2004) investigated the word choice of European Americans, more acculturated Chinese Americans, and less acculturated Chinese Americans when describing emotional events and found that even when asked to speak English, less acculturated Chinese Americans used more somatic and social words than European Americans. Therefore, the way that Chinese speakers process emotional words could differ substantially from the way that speakers of alphabetic languages do. Despite this, the somatic character of Mandarin emotional words makes predictions from embodied semantics more plausible than those from amodal semantics.

The present ERP study aims to investigate, for the first time, to our knowledge, the brain spatiotemporal dynamics of processing emotional words in Mandarin and how it may differ from an alphabetic language. To this end, following a previous study performed in French (Ponz et al., 2014), we examined the processing of emotional words employing a Go/NoGo semantic categorization task in which the participants decided whether each word referred to a vehicle (pressing a response key) or not (withholding from responding). Therefore, no judgment was requested about disgust-related or neutral words themselves; in other words, the emotional contents were processed implicitly. Three types of words were selected as experimental materials: disgust-related words (target stimuli), neutral words (controlling baseline), and vehicle names (fillers).

We expected to identify emotional effects on both early and late ERP components as reviewed above. The time course of the neural response observed in the ERPs could provide important information. The sensitivity of early components (e.g., N2, P2, or EPN) to disgust-related words would index an automatic attentional response to emotional features of words during lexical access. By contrast, later components (N400, LPC) showing the effects of disgust-related words would indicate post-lexical elaboration processes. Indeed, the source estimation of the effects allowed us to see whether and when the insula gets involved. As reviewed above, the activation of the insula occurs when processing disgust stimuli of various modalities, such as facial expressions (Phillips et al., 1997) and pictures (Wright et al., 2004). Since Chinese speakers tend to use somatic words to express emotions, it is expected that the processing of disgust-related words in Mandarin will show strong neural embodiment responses, that is, these words may elicit similar ERP components and source localizations as those reported in Ponz et al.'s study, including enhanced EPN, N400, and LPC compared to neutral words, and even earlier activation of the anterior insula. On the other hand, the amodal theory would predict null effects of disgust-related words in Mandarin. According to the amodal theory, the insula would not play any significant role in processing disgust-related words, given the fact that word meaning consists of amodal symbols.

Material and Methods

2.1 Participants

A total of 21 Chinese college students (12 females), all native speakers of Mandarin Chinese, with ages ranging from 18 to 25 (M = 20.14), all right-handed, with normal or corrected-to-normal vision and no history of psychiatric or neurological disorders, participated in the experiment. All participants participated voluntarily in the experiment and received money for their participation. Two participants were excluded from the final analysis due to the excessive number of artifacts in their EEG data.

2.2 Material[2]

Eighty-two disgust-related words were initially selected. Thirty college students who did not participate in the experiment rated the words on a 9-point disgust scale (1 = not disgusting at all, 9 = extremely disgusting). Only words with rating scores over 5 were retained (M = 6.30, SD = .98). Sixty-three words met this criterion. Then 63 neutral words were selected from a Chinese emotional words database (Yao et al., 2017). Another group of 46 college students rated these words on their valence, arousal, and imageability on a 9-point scale (1 = extremely negative, not arousing at all, extremely difficult to image, 9 = extremely positive, extremely arousing, extremely easy to image). The disgust-related words and the neutral words were matched for their arousal, imageability, and strokes (disgust-related words were naturally more negative). The frequency of the words was obtained from the Modern Chinese Frequency Dictionary (Wang et al., 1986). After controlling the lexical variables, 60 disgust-related words and 60 neutral words were selected as experimental material. An additional set of 50 vehicle names were selected as fillers. The details of the lexical variables were shown in Table 1.

[2] See the questionnaire used for the normative study in Appendix 1, and the selected materials of the experiment in Appendix 2, at the end of the thesis.

Table 1 Lexical Variables of Experimental Material

Variables	Disgust-Related		Neutral		*p*-Value
	M	SD	M	SD	
Valence*	1.81	.38	4.58	.37	.00
Arousal	4.35	.35	4.48	.64	.16
Imageability	5.87	.72	5.58	1.31	.13
Strokes	18.40	5.21	18.45	4.34	.96
Frequency of Use	5.92	12.73	7.12	7.94	.54

* $p < .05$

2.3 Procedure

In the present study, a semantic categorization task was used to investigate the brain spatiotemporal dynamics during the processing of Mandarin disgust-related words. Participants were seated comfortably in a chair in a sound-attenuated room. Materials were presented on a computer screen about 80 cm away from the participants. Participants were instructed to silently read each presented word and identify as quickly and accurately as possible whether it was a vehicle or not. If yes, they were asked to press "J" on the keyboard with the index finger of their right hand. If not, they were asked to stay still. All words were presented randomly. Each participant read 170 trials including 60 disgust-related words, 60 neutral words, and 50 vehicle names. The words were presented in white color (Song typeface, size 36) on a black background. Before the presentation of the word, a fixation cross appeared on the screen for 500 ms, after which the word was presented on the screen for 1000 ms. Participants made their decisions during the presentation of the word. The word presentation was followed by a 500 ms blank and then a signal for eye blinking lasting for 2500 ms. Before the experiment started, participants completed 20 practice trials to familiarize themselves with the experimental procedure (see Figure 1). The material presentation was conducted using E-Prime software.

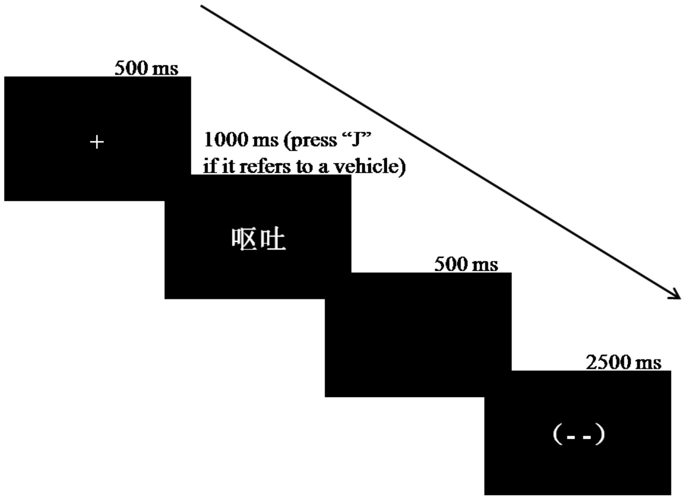


Figure 1 Experimental Procedure (the word means "vomit" in English)

2.4 EEG recording and analysis

The EEG data were collected with a 64-electrode cap (Brain Products) placed according to the extended International 10/20-system. Electrode impedances were kept below 5 Ω during the recording session. All electrodes were re-referenced offline to the average of all electrodes. For each trial, the ERP recording was time-locked to the onset of the word, and ERP analysis was applied to an epoch extending from 200 ms before to 1000 ms after the onset. The preprocessing of the EEG data was conducted using Fieldtrip (Maris & Oostenveld, 2007; Oostenveld et al., 2011). Ocular and motor artifacts were corrected for each participant by running Independent Component Analysis (ICA). The 200 ms preceding the word onset were used for baseline correction.

Epochs showing amplitude values exceeding ± 70 μV in all electrodes were automatically removed. The average number of remained trials was 45 (SD = 5.6) for disgust-related words and 45 (SD = 4.6) for neutral words.

Artifact- and error-free epochs of each participant were averaged for each experimental condition using the Fieldtrip toolbox. The ERPs were analyzed using the cluster-based random permutation method implemented in Fieldtrip. This method performs multiple comparisons in space and time by identifying clusters of significant differences between experimental conditions over the whole ERP segment while effectively controlling for type 1 error.

This statistical method allows only for pair-wise comparisons. For the current study, each of the two conditions was calculated for each participant, and then the waveforms were statistically compared to each other.

2.5 Source localization

Source localization was conducted using the standardized low-resolution brain electromagnetic tomography (sLORETA) (Pascual-Marqui, 2002). This is a method that computes images of electric neuronal activity from EEG. sLORETA calculates the standardized current density at 6239 voxels at 5mm spatial resolution within a head model of the MNI-reference brain. For each participant, sLORETA images corresponding to ERP components with significant differences were defined as the mean current density values for the time windows of interest and were corrected for multiple comparisons. Statistically significant difference was set to $p < .01$ to obtain the most prominent differences in brain region activations between the two categories of stimuli.

Results

3.1 Behavioral results

The mean accuracy of the vehicle identification task was 97.6% (SD = 0.03) and the mean response time was 561.32 ms (SD = 58.17). The rate of false alarms for disgust-related words was 0.2% (SD = .01) and for neutral words 0.2% (SD = .01). The high level of accuracy indicated that participants fully understood the requirements of the experiment and paid attention to the stimuli. The mean response time suggested that the duration of each trial (1000 ms) was sufficient for participants to process the meaning of the word.

3.2 ERP results

When disgust-related and neutral trials were compared, three temporal clusters of differences were identified using the randomization method described in the section 'ERP recording and analysis' (Figure 2).

3.2.1 Early time window (anterior: 170-232 ms; posterior: 196-236)

Two significant temporo-spatial clusters were identified in time windows coincident with the P2 and the EPN components. One extended between 170 and 232 ms after stimuli onset and revealed more positive amplitudes for disgust-related than for neutral words over fronto-central electrodes (Tmaxsum = 1042, p = .012), corresponding to the P2 component. The other overlapped temporally with the previous one (196-236 ms) but showing more negative amplitudes for disgust-related than neutral words over occipital and left parieto-occipital electrodes (Tmaxsum = 529, p

= .046), likely representing an instance of the EPN component.

3.2.2 Late time window (315-600 ms)

The next significant cluster occurred between 315 and 600 ms after the word onset and was characterized by more reduced centro-parietal amplitudes for disgust-related than for neutral words (Tmaxsum = 5265, $p < .001$). The timing and topographical distribution of this cluster reflected a sustained effect encompassing both the N400 and the LPC components.

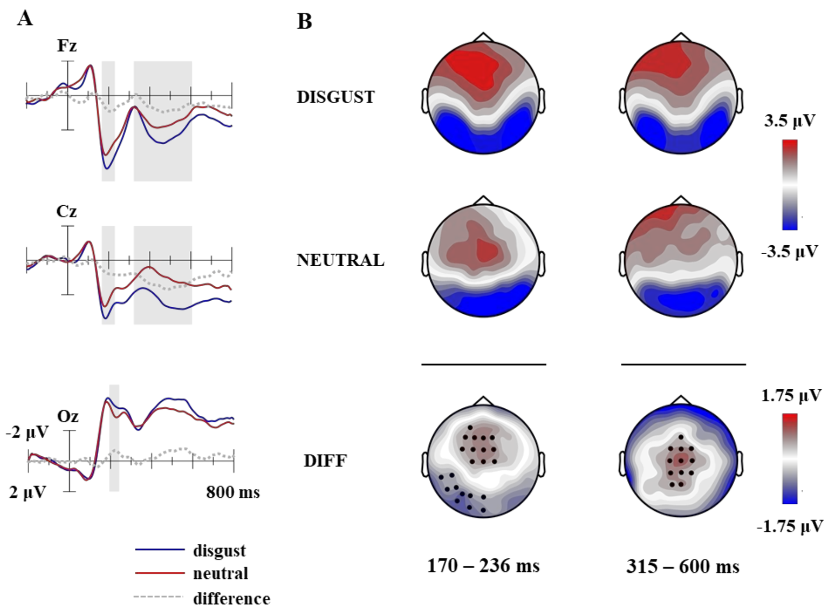


Figure 2. (A) Averaged ERP waveforms at medial scalp sites (Fz, Cz, Oz electrodes) for disgust-related words and neutral words. Grey shaded areas highlight the time windows of the significant differences between disgust-related words and neutral words. (B) Scalp distribution of voltage in the two time windows (170-236ms and 315-600ms) for disgust-related words, neutral words, and the differences between them (disgust – neutral). Black points highlight the scalp sites corresponding to the significant cluster-base differences.

3.3 Source localization

sLORETA was used to conduct source localization for the ERPs identified above. Source localization for the N400 component of the two experimental conditions failed to reach a converging result. However, for the early time window, disgust-related words generated higher current density than neutral words in the insula, uncus and superior temporal gyrus, and anterior cingulate, cingulate gyrus, and posterior cingulate. The inferior temporal gyrus and middle temporal gyrus also demonstrated stronger activations for disgust-related words (Table 2 and Figure 3).

In the late window, higher current density was found for disgust-related words in the precuneus in addition to the posterior cingulate and cingulate gyrus (Table 3 and Figure 4) during the positive-going segment of the cluster that resembles the LPC component.

Table 2 Locations of disgust-related words eliciting higher current density in the 170-232 ms time window than neutral words. The critical t-value for $p = .01$ is 4.65

Structure (BA)	MNI Coordinates	t-Value
Fusiform Gyrus (20)	40, -10, -30	6.47
Inferior Temporal Gyrus (20)	40, -10, -35	6.51
Insula (13)	40, -5, -5	4.88
Middle Temporal Gyrus (21)	40, -5, -35	6.28
Middle Cingulate Gyrus (31)	0, -35, 45	4.74
Parahippocampal Gyrus (35)	25, -15, -30	4.70
Postcentral Gyrus (2/3)	-35, -25, 40	5.40
Precuneus (7)	0, -40, 45	4.82
Superior Temporal Gyrus (13/21/22/38)	45, -5, -10	5.53
Uncus (20/28)	35, -10, -40	5.98

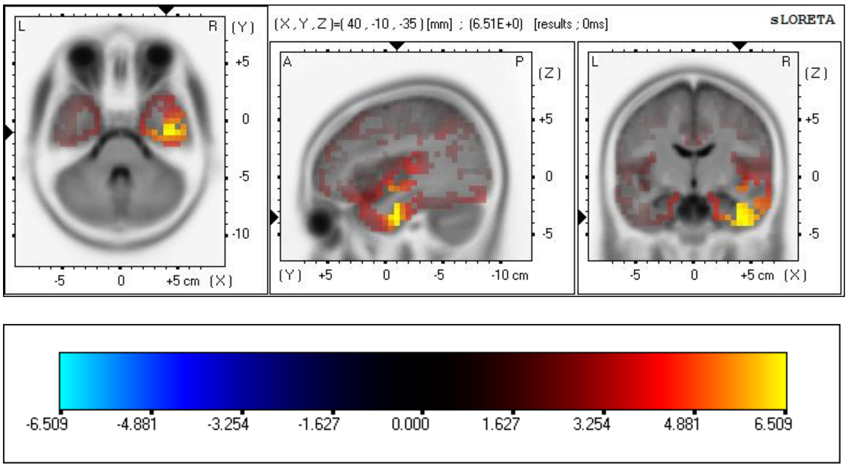


Figure 3 sLORETA images of the 170-232 ms time window with axial, sagittal, and coronal views. The color scale corresponds to the t-values of differences between disgust-related and neutral words.

Table 3 Locations of disgust-related words eliciting higher current density in the 315-600 ms time window than neutral words. The critical t-value for $p = .01$ is 4.50

Structure (BA)	MNI Coordinates	t-Value
Precuneus (7/31)	-10, -50, 35	4.57
Posterior Cingulate Gyrus (31)	-10, -45, 40	4.70

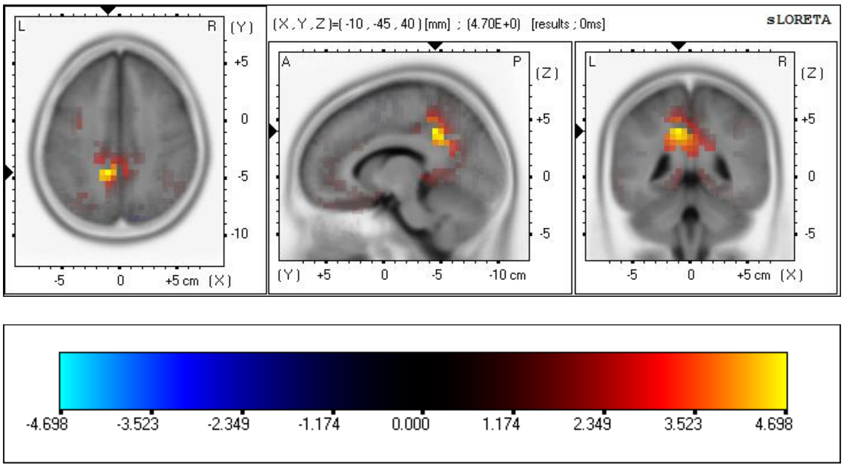


Figure 4 sLORETA images of the 315-600 ms time window with axial, sagittal, and coronal views. The color scale corresponds to the t-values of differences between disgust-related and neutral words.

Discussion

In the present study, we used a semantic categorization task to investigate the spatiotemporal brain dynamics in the processing of Mandarin emotion words. Compared to neutral words, disgust-related words modulated both early (170-236 ms, P2 and EPN) and late (315-600 ms, N400 and LPC) ERP components. As for the source estimation, the insula, together with other sensory and emotion-related brain structures, became more activated for disgust-related words compared to neutral words in the early time window. Furthermore, robust activations of precuneus (an action-related structure) were obtained for disgust-related words in the late time window.

The positive-going waveform around 200 ms is similar in time and distribution to the P2 component (see Figure 2 for details). The enhanced P2 obtained here for disgust-related words confirms the results of several previous studies with different kinds of stimuli and modalities (Ding et al., 2016; Herbert et al., 2006; Kanske & Kotz, 2007; Wang et al., 2013). P2 is taken as a possible index of attention orientation to emotional stimuli (Citron, 2012) and is responsible for the conscious processing of emotional content (Herbert et al., 2006). Therefore, the enhanced P2 component suggests that disgust-related words demand more attention than neutral words in our Chinese participants, indicating early processing of emotional features for Mandarin words. In addition, enhanced EPN-like negativity was detected for disgust-related words compared to neutral words in occipital and left parieto-occipital sites during the 196-236 ms time window. The EPN component is commonly found in emotion-related studies and has been associated with automatic attention allocation during the initial stages of accessing to emotional information (Schupp et al., 2004) and is usually enhanced by emotional words (Franken et al., 2009; Hinojosa et al., 2010; Palazova et al., 2011; Schacht & Sommer, 2009; Scott et al., 2009). Once again, the enhanced EPN component demonstrates the early attention allocation on processing Mandarin disgust-related words.

In the later time window, disgust-related words elicited smaller negativity than neutral words from 315 ms onward, and this effect was more pronounced in the more medial-posterior areas. The initial period of this sustained effect resembles the N400 component commonly found in semantic processing tasks, indexing lexical access (Lau et al., 2008), and lexico-semantic integration processes (Kutas & Federmeier, 2000). The attenuation of N400 for emotional stimuli has been reported in previous studies and generally interpreted as reflecting the facilitation of lexical-semantic processing for emotional stimuli (Herbert et al., 2006; Kanske & Kotz, 2007). However, in Ponz et al.'s (2014) study, using the same Go/NoGo paradigm, the authors found enhanced rather than attenuated N400 for disgust-related words in conflict with other studies in the literature (Herbert et al., 2008; Kanske & Kotz, 2007) and with the effect reported here.

Following the N400-like difference, disgust-related words elicited larger positivity than neutral words in what appears to represent an instance of the LPC component. The enlargement of the LPC amplitude has been found in almost every emotion-related study (Citron, 2012). In the present study, the enhanced LPC amplitudes associated with disgust-related words were in line with the traditional pattern reported elsewhere (Carretié et al., 2001; Herbert et al., 2006; Palazova et al., 2011), indicating a post-lexical process of deep and deliberate analysis of emotional contents in disgust-related words. More controlled and explicit processing of emotion usually occurs during the time window of this late component, indicating additional cognitive processes devoted to either the refinement and contextual integration of the emotional content or the sustained attention toward motivationally relevant stimuli (Fischler & Bradley, 2006; Schupp, Junghöfer, Öhman, et al., 2004).

Concerning the neural sources for the early time window effects, it is remarkable that the activation of the anterior insula is associated with disgust-related words, confirming other results in the literature reporting the special role of this structure in processing disgusting stimuli of various modalities (Huang et al., 2010). In addition, regions are activated generally associated with orthography processing and object recognition, including the fusiform gyrus, the middle temporal gyrus, and the inferior temporal gyrus (Acheson & Hagoort, 2013; Devlin et al., 2006; Spiridon et al., 2006). However, since the disgust-related and neutral words were controlled for critical psycholinguistic variables, the differential activations in those regions suggested that the disgust-related words were more deeply processed as they drew more attention and were intrinsically important to human survival (Rozin & Fallon, 1987; Woody & Teachman, 2006). The observed activation of the precuneus for disgust-related words could be related to attention directing when a person imagines or prepares movements (Cavanna & Trimble, 2006; Kawashima et al., 1995), thus indicating that the disgust-related words, though not as straightforward as images or facial expressions, still elicited withdrawal behaviors (Woody & Teachman, 2006). This claim is further supported by the observed activations of the postcentral gyrus associated with the primary somatosensory cortex (Case et al., 2016). Also, the more robust activations of cross-modality brain structures for disgust-related words including the parahippocampal gyrus are involved in scene recognition (Mégevand et al., 2014); the uncus, part of the olfactory cortex, also suggested that our participants simulated the referents of the presented words in their minds during the experiment. The activations of other emotion-processing structures such as the cingulate gyrus (Hadland et al., 2003) in this early time window also proved that disgust processing in Mandarin words extends beyond the written word processing system.

The results of the present study clearly support the theory of embodied semantics in the processing of disgust-related words. Previous studies of embodied cognition suggested that some semantic contents are grounded in perceptual-motor and emotional processing (Barsalou, 2008; Horchak et al., 2014; Niedenthal, 2007). Pulvermüller et al.'s studies show that semantic activation can occur as early as 200 ms after the word onset and spread to non-linguistic content-related brain regions (Pulvermüller, 2005). For instance, action words, such as 'pick' and 'kick', activated brain regions somatotopically corresponding to hand and foot areas. As for words denoting emotions, they could activate motor programs associated with the expression of the corresponding emotions (Dreyer et al., 2015; Lugli et al., 2012; Moseley et al., 2012; Mouilso et al., 2007; Wittgenstein, 1958), as well as the general neural network of emotions, including the insula and the amygdala (Jones et al., 2010; Kanske & Kotz, 2011; Lewis et al., 2007; Nakic et al., 2006; Ponz et al., 2014; Straube et al., 2011). Therefore, the early activation of the anterior insula during the processing of Mandarin disgust-related words indicates that readers of this language recruit emotion-related (not only motor) networks as part of their meaning. These facts support the theory of embodiment semantics rather than the amodal theory.

Generally speaking, the current results with Mandarin converge with the results from previous studies with Indo-European languages and alphabetic writing systems. However, some differences between the study of Ponz et al. (2014) performed with French-speaking participants and the present study are remarkable. Ponz et al. reported larger EPN and N400 amplitudes for disgust-related words than neutral words, associated with increased activation of the insula. To explain their results, the authors proposed that the N400 component associated with emotional words indexes difficulty in inhibiting them. Participants in that study were instructed to focus on vehicle words (Go trials) and ignore the others (NoGo trials), and they found it harder to ignore disgust-related words than neutral words. By contrast, in the present study, performed with Chinese participants with the same Go/NoGo procedure, there was reduced negativity for disgust-related words in the N400 time window, which may indicate that Mandarin Chinese readers, unlike French readers, succeeded in inhibiting responses when reading disgust-related words. Instead, the earliest difference obtained here between disgust-related and neutral words was manifested on the P2 and the EPN components, associated with enhanced activity of the insula. The EPN and P2 are identified in similar time windows and could be equally sensitive to emotional stimuli, but they differ in scalp distribution (Citron, 2012). Ponz et al. (2014) attributed the absence of P2 in their study to the particular task requirements of the Go/NoGo paradigm. However, in the present study, we used exactly the same paradigm and found that the P2 component was sensitive to the emotional manipulation of words. Such different results could derive from the different cognitive demands of the alphabetic and Mandarin writing systems. The P2 component has consistently been found in Mandarin-related studies but not in alphabetic language studies (Chen et al., 2007; Kong et al., 2010, 2012; Q. Zhang et al., 2009). P2 is viewed as a component reflecting the processing of orthographical and phonological features of words, and the absence of this component in studies with alphabetic language could be ascribed to the close relationship between the letter and the pronunciation, which triggers earlier components than P2 (Xie et al., 2016). But beyond this orthographic explanation, we infer that in Mandarin, the emotional sensitivity to disgust-related words occurs earlier than in French. Such an inference is further supported by the fact that the activation of the insula of our Chinese participants occurred during the P2 time window instead of the N400 time window in Ponz et al.'s study. Moreover, a similar EPN pattern was detected in the present experiment but occurred earlier and overlapped with the P2, which further testified the early processing of disgust in Mandarin words. Finally, the present study significantly increased the number of trials compared to the previous study (170 vs. 94) so that statistical power was increased. Nevertheless, both Ponz et al.'s study and the present one can illustrate the point that the embodiment theory of lexical emotional meaning is culturally and linguistically universal.

Conclusion

The present study determines the spatiotemporal brain dynamics of emotion processing in Mandarin, using disgust as the specific emotion. Early effects of emotion were identified on the P2 component instead of EPN for Mandarin Chinese word processing, indicating a fast reaction to the emotional value of words. Moreover, this early effect was associated with the activation of the insula, which is the neural locus of disgust processing across various modalities. Further semantic processing of emotion features indexed by the negativity during the N400 time window was inhibited among Chinese participants. Taken together, the results of the current study extend the results of previous studies to the Mandarin language in support of the theory of embodiment semantics on written word processing. When processing emotional content in Mandarin words, cross-modality sensory activation occurs in the brain along with semantic comprehension being decoded.

EXPERIMENT 2[3]

Learning new words' emotional meanings in the contexts of faces and sentences

Abstract: Language is a powerful vehicle for expressing emotions, although the process by which words acquire their emotional meaning remains poorly understood. This study investigates how words acquire emotional meanings using two types of associative contexts: faces and sentences. To this end, participants were exposed to pseudowords repeatedly paired either with faces or with sentences expressing the emotions of disgust, sadness, or neutrality. We examined participants' acquisition of meanings by testing them in both within-modality (e.g., learning pseudowords with faces and testing them with a new set of faces with the target expressions) and cross-modality generalization tasks (e.g. learning pseudowords with faces and testing them with sentences). Results in the generalization tests showed that the participants in the Face Group acquired disgust and neutral meanings better than participants in the Sentence Group. In turn, participants in the Sentence Group acquired the meaning of sadness better than their counterparts in the Face Group, but this advantage was only manifested in the cross-modality test with faces. We conclude that both contexts are effective for acquiring the emotional meaning of words, although acquisition with faces is more versatile or generalizable.

Keywords: emotion acquisition, face, sentence, pseudoword

[3] Experiment 2 has been accepted for publication in the journal *Psicológica*. It is currently in press.

Introduction

An important semantic dimension of words is their emotional valence. Some words refer to pleasant or positive concepts (party, intelligence), whereas others refer to unpleasant or negative concepts (pandemic, cancer). Moreover, these words can work as powerful emotional stimuli themselves, inducing neural activities similar to those induced by emotional facial expressions or emotional pictures (Citron, 2012; Schacht & Sommer, 2009). But how do words acquire their emotional connotations? One possibility is that associative learning plays a role, as these words could repeatedly co-occur with specific emotional stimuli in daily experience. For instance, the disgusting connotation of some words (vomit, cockroach) could be induced by their associations with the corresponding perceptual stimuli, as well as with proprioceptive reactions or with facial expressions of disgust. The present study investigates the acquisition of emotional connotations for new words using two different associative contexts: faces and sentences. Despite the potential relevance of these two associative mechanisms, to our knowledge, no comparison has ever been conducted to explore which of the two mechanisms induces words' emotional meaning more efficiently.

Facial expressions are effective communication channels (Brosch et al., 2008; Darwin, 1872) and an essential component for expressing emotions (Ekman, 1992a, 1993; Russell et al., 2003). There is experimental evidence that emotional words and facial expressions are strongly associated in one's semantic memory, interfering with each other in Stroop tasks (Baggott et al., 2011; Beall & Herbert, 2008; Kar et al., 2018; Stenberg et al., 1998). Even in late bilinguals, processing emotional words in the second language triggers motor potentials in specific face muscles (Baumeister et al., 2017) and induces word-face conflicts in Stroop tasks (Fan et al., 2016, 2018). However, the emotionality of second-language words is considerably reduced compared to that of first-language words, because the processing of meaning is more direct and automatic in the first language than in the second language (Kroll & Stewart, 1994; Opitz & Degner, 2012; Pavlenko, 2012). In addition, studies on how children acquire emotion concepts have found that they initially recognize emotions through the facial expressions of their caregivers (Denham, 1998; Izard, 1971) and later acquire linguistic labels for concrete emotions as their language proficiency improves (Markham & Adams, 1992; Vicari et al., 2000). For adults, emotions could also be recognized both through other people's facial expressions and by being associated with words referring to emotional states and events (Kissler et al., 2009; Niedenthal et al., 2002; Padmala et al., 2011).

Previous associative learning studies have shown that associating neutral facial expressions with emotional facial expressions modifies the affective evaluation of the former in both healthy participants (Walther, 2002) and dementia patients (Blessing et al., 2013). However, whether such an effect exists in the acquisition of emotional valence for new words remains unclear. Since facial expressions are one of the first accessible sources of emotion acquisition for humans, and they are strongly associated with emotional words in adults' memory, we expected that face-new word associations will play an important role in the acquisition of words' emotionality.

Another possible scenario for acquiring new word meaning is in the context of other words or sentences. This is quite common for adults when they learn low-frequency words in their own language or new words in a second language (Chaffin et al., 2001; Landauer & Dumais, 1997; Lindsay & Gaskell, 2010). In the laboratory, experiments pairing new words with linguistic contexts succeeded in inducing lexical representations. For instance, in a study by Frishkoff and colleagues (2010), participants received novel words embedded in informative sentences. In a second session, the trained new words compared to untrained new words showed ERP signatures similar to those for familiar words and modulated the N400 in a semantic priming paradigm.

Moreover, numerous laboratory studies have suggested that emotional words can modify the emotional valence of neutral words. For instance, neutral words can acquire emotional connotations through pairing with emotional words even in the absence of contingency awareness (de Houwer et al., 1994, 1997). Such an effect has been found even when nonsense trigram syllables were paired with emotional words (A. W. Staats & Staats, 1959; C. K. Staats & Staats, 1957). Note, however, that in real life, when we look an unfamiliar word up in the dictionary, the meaning of the word is usually explained with more detailed information than just a single word. It thus seems more realistic to use sentences describing certain emotion- inducing scenarios for emotion acquisition than to use single words. But only a few studies have adopted such a design. An interesting exception was the study reported by Junghofer and colleagues (2017), in which sentences describing either a neutral occupation of a person or a criminal activity were paired with neutral faces. After training, neutral faces were considered less pleasant and induced more extensive brain activity when associated with criminal rather than neutral behaviours. In the current research, as far as we know, we use for the first time sentences as a learning context to induce emotionality in new words.

Previous studies investigating contextual emotion acquisition have focused on the difference between emotional and neutral valences. Behavioural research suggests that pseudowords associated with negative pictures are better remembered than those associated with neutral pictures (Eden et al., 2014). Evidence from EEG studies suggests that pseudowords with acquired emotional and neutral connotations differ in an early time window and in the P300, indicating that contextual learning using pictures is suitable to establish emotional associations in words (Fritsch & Kuchinke, 2013). The present study intends to go further by examining the acquisition of specific emotional connotations, beyond general differences in affective valence. With this aim, in this study two types of negative stimuli, disgust and sadness, as well as neutral stimuli were paired with pseudowords to induce the acquisition of emotional meanings. We chose the two negative emotions for several reasons. Firstly, we were primarily interested in the study of disgust, one of the six primary emotions (Ekman, 1992b), which has been relatively neglected in the field of emotional language. Secondly, rather than establishing a gross contrast with a positive emotion like happiness, we wanted to contrast it with another negatively valenced emotion. Moreover, happiness, the only primary positive emotion, is more effectively induced by pictures, real-life experiences, or videos than by single sentences (Ferrer et al., 2015; Yan & Dillard, 2010). Thirdly, we chose sadness as a contrasting emotion for disgust because they have several distinctive features: disgust is mainly triggered by external physical stimuli (Rozin & Haidt, 2013), whereas sadness is a more internal and psychosocial emotion (Mikulincer & Florian, 1997); moreover, the two emotions differ in facial expressions. We are aware that other negative emotions such as fear or anger are also very distinctive and easy to identify in face recognition tasks (Adolphs et al., 1999; Mattavelli et al., 2014). However, like disgust, they are generally reactions to threatening stimuli (Spielberger & Reheiser, 2010), while sadness differs from disgust as it is the response to the loss of valuable stimuli or goals (Lench et al., 2011). The neutral emotion condition was included as a control baseline.

Disgust is induced by specific types of aversive stimuli (Rozin et al., 1994). Unique facial expressions and physiological responses can be induced by the emotion of disgust. For facial expressions, nose wrinkle, gape, tongue extrusion, and raised upper lips were reported to be associated with disgust (Rozin et al., 1994). Psychophysiological responses including nausea, reduced heart rate, amplified skin conductance (Stark et al., 2005), and decreased respiratory rate (Ritz et al., 2005) are induced when contacting disgusting stimuli. Stimuli inducing disgust usually come with the threat of contamination or disease and feeling disgust encourages withdrawal behaviours (Woody & Teachman, 2006). Therefore, disgust protects us from noxious substances that may harm us or reduce our wellbeing (Rozin & Fallon, 1987). Previous studies also suggested that viewing disgust facial expressions would activate the insula, which is the main neural structure involved in disgust processing (Jabbi et al., 2008; Wicker et al., 2003).

Sadness, on the other hand, results mainly from loss (Carver, 2004; Lench et al., 2011; Levine & Pizarro, 2004) and failure (Lench et al., 2011). Sadness can be induced by social and non-social situations of loss (Keltner & Kring, 1998) and relevant facial expressions are associated with reduced sympathetic (lower skin conductance level, lengthened cardiac pre-ejection period) and increased parasympathetic (higher respiratory sinus arrhythmia) activities (Marsh et al., 2008). Sadness, while sharing a negative valence with disgust, is more endogenously oriented (Lench et al., 2016) and is often characterized by a facial expression that lowers the corners of the mouth and raises the inner portion of the brows (Ekman et al., 2002).

According to previous studies, the facial expressions of disgust elicit stronger activation of the defensive motivational system and the orientation response than the those of sadness (Gantiva et al., 2019). Therefore, it is expected that the associative context of faces will be more advantageous for the acquisition of disgusting connotations than sad connotations for new words. In addition, it is thought that faces will be more effective than sentences for acquiring disgust-related meanings, as faces are simpler and more straightforward. On the other hand, sentences can demonstrate advantages for the acquisition of sadness over disgust, as sentences are able to describe scenarios that are more specific, which are compatible with the endogenous nature of sadness (Lench et al., 2016).

This study aims to explore the acquisition of words' emotional meanings using faces and sentences as two different associative contexts. To this end, participants were divided into two different groups to acquire disgusting, sad, and neutral emotional connotations for pseudowords through either faces (Face Group) or sentences describing emotion-related scenarios (Sentence Group). The experimental design included a Learning Phase and an Evaluation Phase. In the Learning Phase, pseudowords repeatedly associated with either faces or sentences were presented to participants in three blocks. After each block, there was a block learning test to instantly probe participants' learning of the associations between the pseudowords and the particular faces or sentences presented in the learning block. When the Learning Phase was finished, participants proceeded to the Evaluation Phase, comprising a pseudoword matching test, a within-modality generalization test, and a cross-modality generalization test. The Evaluation Phase was designed to assess whether the learned pseudowords acquired emotional connotations after their repetitive associations with emotional stimuli.

Methods

Participants

Eighty-four native Spanish-speaking and physically and mentally healthy college students from the University of La Laguna (Spain) participated in the experiment in return for course credits. All participants were right-handed with normal or corrected to normal vision. Half of the participants were randomly assigned to the Face Group, learning the associations between pseudowords and faces, while the remaining participants were assigned to the Sentence Group to learn the associations between pseudowords and sentences. Two participants in the Face Group and one participant in the Sentence Group were excluded from the analyses for their excessive errors in the Learning Phase (accuracy < 60%).

Materials

Thirty pseudowords of 5-7 letters were composed with the first two letters being "al", "ro", and "le", respectively. Forty-five faces were selected for the Face Group (15 disgusting, 15 sad, and 15 neutral). The faces were selected from the KDEF (Lundqvist et al., 1998) stimuli set. The experimental face stimuli portrayed 15 individuals (eight females: KDEF no. 01, 02, 05, 07, 09, 11, 13, and 14; and seven males: KDEF no. 10, 11, 12, 13, 17, 22, and 23), each showing one of the three expressions (disgust, sadness, and neutral). Non-facial areas (e.g., hair) were removed by applying an ellipsoidal mask. The arousal data of the faces were obtained from the KDEF documents (Karolinska Directed Emotional Faces (KDEF) documents — Department of Experimental Clinical and Health Psychology — Ghent University, n.d.) (see Table 1). There was a significant effect of emotion, F (1, 44) = 22.596, p < .001, η^2 = .518. Post-hoc tests showed that disgust and sadness faces were significantly more arousing than neutral faces (p < .001), and there was no significant difference of arousal between disgust and sadness faces (p = .520). The faces were presented against a black background. Each face stimulus was 11.5 cm high by 8.5 cm wide, equalling a visual angle of 9.40° (vertical) × 6.95° (horizontal) at 70-cm viewing distance.

Table 1. Means and Standard Deviations of arousal of the faces used in the experiment.

	AROUSAL
EMOTION	
disgust	3.57 (0.5)
sadness	3.41 (0.4)
neutral	2.64 (0.3)
overall	3.21 (0.6)

For the Sentence Group, 54 emotional sentences were composed to describe disgusting, sad and neutral scenarios. 39 students of the same college population who did not participate in the final experiment rated the emotions expressed by the sentences through online questionnaires[4]. Participants were asked to select the emotional label (neutral, sadness, happiness, disgust, or anger) that best fit the emotion connoted by the sentences, and to rate how confident they felt about their choices on a 5-point scale (1-a little sure, 5-completely sure). Another group of 32 college students rated the arousal of the sentences in a different questionnaire, over a 5-point scale (1-very peaceful, 5-very exciting). Only sentences with 70% or more choices of the intended emotion were retained (see Table 2). The average categorization rates of the retained disgusting, sad, and neutral sentences were 88.89% (SD = 9.91%), 89.74% (SD = 8.78%), and 89.74% (SD = 9.84%), respectively. In total, 45 emotional sentences were used for the experiment (15 disgusting, 15 sad, and 15 neutral). Critically, there was no significant difference among the sentences of the three emotional categories in intended emotion choice rates, F (1, 44) = .027, p = .973, η^2 = .001, or confidence scores, F (1, 44) = .102, p = .903, η^2 = .005. For arousal, there was a significant effect of emotion, F (1, 44) = 119.327, p < .001, η^2 = .850. Post-hoc tests showed that disgusting sentences and sad

[4] See questionnaires used for the normative studies in Appendix 3, and selected materials in Appendix 4, at the end of the thesis

sentences were significantly more arousing than neutral sentences ($p < .001$) and there was no significant difference of arousal between disgusting and sad sentences ($p = .916$). The mean arousal scores for disgusting, sad, and neutral sentences were 4.32 (SD = .393), 4.25 (SD = .671), and 1.84 (SD = .380), respectively. The sentences were presented against a black background in Times New Roman font, size 30.

Table 2. Means and Standard Deviations of the categorization rates (percentage), choice confidence scores, and arousal of the sentences used in the experiment.

	CATEGORIZATION RATES	**CHOICE CONFIDENCE SCORES**	**AROUSAL**
EMOTION	%		
disgust	88.89 (10)	4.64 (0.2)	4.32 (0.4)
sadness	89.74 (9)	4.62 (0.3)	4.25 (0.7)
neutral	89.74 (10)	4.40 (0.2)	1.84 (0.4)
overall	89.46 (9)	4.55 (0.3)	3.47 (1.3)

In total, 30 pseudowords, 45 faces, and 45 sentences were used in the experiment. Ten pseudowords were assigned to each emotion category (disgust, sadness, neutral) to pair with 10 faces/sentences of the corresponding emotion, which were presented to participants in the Learning Phase. The 15 remaining faces/sentences were used for the generalization tests in the Evaluation Phase (5 in each emotion category). All 30 pseudowords appeared in all the generalization tests with the correct response counterbalanced across participants as well as the assignment of pseudowords to emotions.

Design and Procedure

The experiment used a mixed 2 x 3 factorial design, with learning procedure (faces and sentences) as between-participant factor and emotion (disgust, sadness, and neutral) as within-participant factor. The Learning Phase consisted of three blocks, each followed by a testing block. The Learning Phase was followed by an Evaluation Phase, as illustrated in Figure 1 and Table 3.

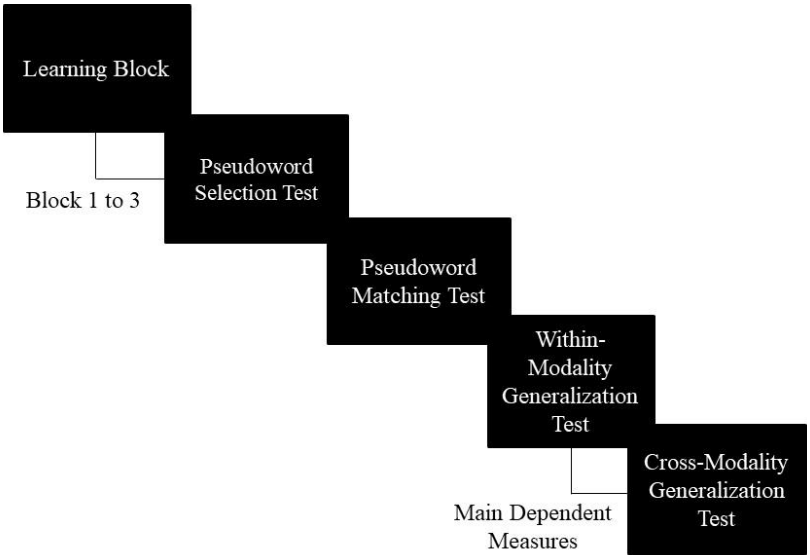


Figure 1. Experimental procedures for both groups

Table 3. Outline of the experimental design.

Two learning groups: faces and sentences The Face Group was presented with pseudowords paired with faces. The Sentence Group was presented with pseudowords paired with sentences.
Three emotions: disgust, sadness, and neutral In both groups the stimuli paired with pseudowords (either faces or sentences) involved disgusting, sad, or neutral emotional connotations.

Main dependent measures:
• <u>Within-modality generalization tests</u>
    o The Face Group was presented with new faces to test how the emotional connotations of pseudowords generalize to unlearned faces.
    o The Sentence Group was presented with new sentences to test how the emotional connotations of pseudowords generalize to unlearned sentences.
• <u>Cross-modality generalization tests</u>
    o The Face Group was presented with sentences to test how the emotional connotations of pseudowords generalize to emotional sentences.
    o The Sentence Group was presented with faces to test how the emotional connotations of pseudowords generalize to facial expressions.

Participants in both groups started the experiment by reading the task instructions. They were asked to memorize the association between the face/sentence and the pseudoword and then to complete the following tests. The instructions did not mention anything about emotion and only the learning and testing blocks were explained. After reading the instructions, participants completed a practice block of 6 learning trials and 3 testing trials. The pseudowords and faces/sentences used in the practice block were not presented during the experiment. Instructions for the Evaluation Phase were given after completing the Learning Phase. Participants' accuracies and response times for the evaluation tests were recorded.

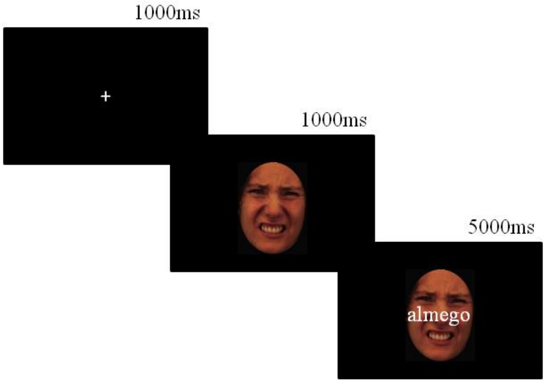
Learning in the Face Group.

The Learning Phase was divided into three blocks. There were four face-pseudoword pairs of each emotion in the first block and three in the second and third blocks. Each pair was repeated six times within each block resulting in 72, 54, and 54 trials in the first, the second, and the third block, respectively. Pseudowords starting with "al", "ro", and "le" were respectively assigned to one of the three emotion pairs. The assignment was counterbalanced across participants. Each trial began with a fixation cross presented for 1000 ms in Times New Roman font, size 30 followed by the face presented for 1000 ms. Then, the pseudoword was presented in Times New Roman font, size 50 in the middle of the screen over the face for 5000 ms (see Figure 2 A). After each learning block, the participant's learning of the associations was evaluated in a pseudoword selection test. Each trial in this test began with a fixation cross presented in Times New Roman font, size 30 for 1000 ms, followed by one of the faces previously seen presented for 1000 ms (see Figure 2 B). Then, two pseudowords from the preceding learning block were presented at the lower- left corner of the screen in Times New Roman font, size 18. The participant was required to select which one had been associated with the face on the screen by pressing "1" on the keyboard for the pseudoword on the left and "2" for the pseudoword on the right (not the keypad) with their left hand. The time limit for response was 5000 ms.

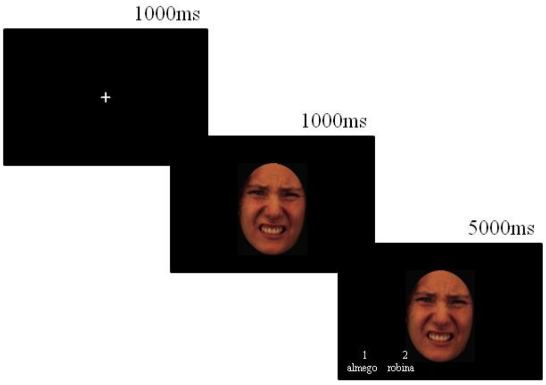
Evaluation in the Face Group.

The first test was a pseudoword matching test, consisting of 30 trials (10 for each emotion) with the following sequence of events: 1000 ms fixation cross in Times New Roman font, size 30, followed by a face from the three learning blocks presented for 1000 ms, and then a pseudoword over the face in Times New Roman font, size 50 with two options of "correct" and "incorrect" at the lower-left corner of the screen in Times New Roman font, size 18 (see Figure 2 C). Participants were asked to judge whether the pairing between the pseudoword and the face was correct according to the associations acquired during the Learning Phase by pressing "1" on the keyboard for "correct" and "2" for "incorrect". The time limit for response was 5000 ms. Like in the pseudoword selection test, the matching test aimed to probe participants' memorization of the association between the faces and the pseudowords. The next two tests included in this Evaluation Phase were designed to investigate whether learned pseudowords acquired emotional connotations, rather than only associations with specific face stimuli. The within-modality generalization test proceeded in the same fashion as the pseudoword selection test, except that here the learned pseudowords of the three emotions were paired with new faces, i.e., faces not previously seen in the Learning Phase (see Figure 2 D). The participant was asked to select among the two pseudowords the one that best described the emotion expressed in the new face by pressing "1" or "2" on the keyboard as he or she did in the pseudoword selection test during the Learning Phase. The time limit for response was 5000 ms. There were 15 test trials in this test (5 for each emotion). The last test was a cross-modality generalization test, as it introduced emotional sentences rather than new faces (see Figure 2 E). The 15 test trials (5 for each emotion) began with a fixation cross presented for 1000 ms in Times New Roman font, size 30 followed by an emotional sentence presented in the middle of the screen for 1000 ms in Times New Roman font, size 30. Then two pseudowords from the previous acquisition blocks were presented at the lower-left corner of the screen in Times New Roman font, size 18. Participants were asked to select the pseudoword that best described the emotion associated with the sentence by pressing "1" or "2" on the keyboard as in the previous test. There was no time limit for response, as such a cross-modality task was more demanding than the previous ones.

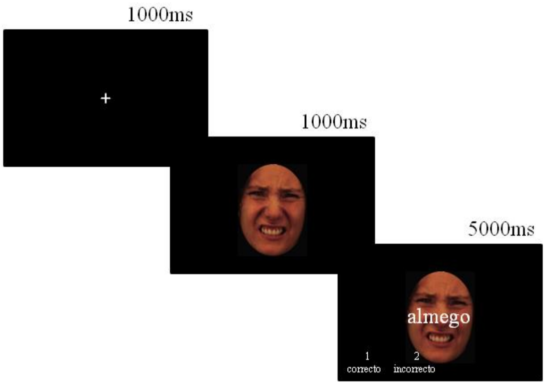
(A) Learning trial



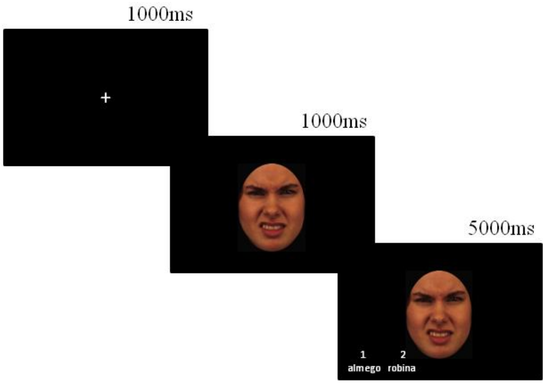
(B) Selection test



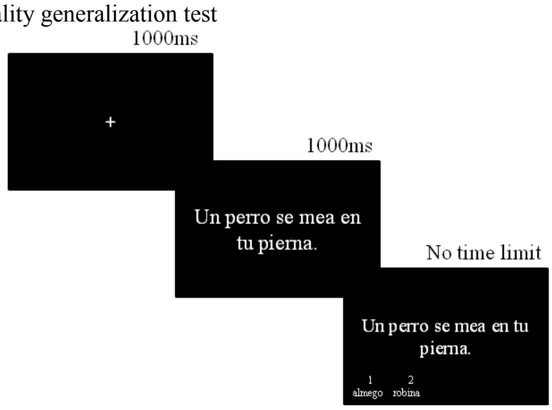
(C) Matching test



(D) Within-modality generalization test



(E) Cross-modality generalization test



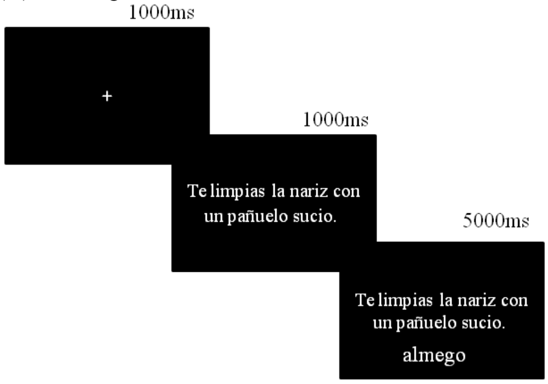
* The English translation of the sentence is "A dog pisses on your leg".

Figure 2. Examples of materials in the Face Group. The English translation of the sentence is "A dog pisses on your leg".

Learning and Evaluation in the Sentence Group.

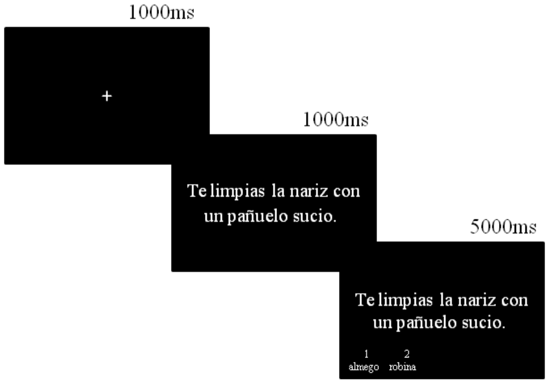
For the Sentence Group, the learning and test procedures were similar to those in the Face Group, except that faces were replaced by sentences in the Learning and the Evaluation Phases. Thus, in the Learning Phase, each pseudoword was presented below a sentence in the middle of the screen (see Figure 3 A). Concerning the pseudoword selection test and the three other tests in the Evaluation Phase, the same format was applied as in the corresponding tests for the Face Group, the only difference being that the faces were replaced with sentences (see Figure 3 B and 3 C). This means that new sentences were used for the within-modality generalization test and faces were used for the cross-modality generalization test (see Figure 3 D and 3 E). Note that the generalization materials used for the within-modality and the cross-modality tests, i.e., new faces and sentences, in the Sentence Group were exactly the same as the ones employed in the Face Group for the cross-modality and the within-modality tests, respectively. All fixations and sentences were presented in Times New Roman font, size 30, the pseudowords in Times New Roman font, size 50, and the options for the tests in Times New Roman font, size 18.

(A) Learning Trial



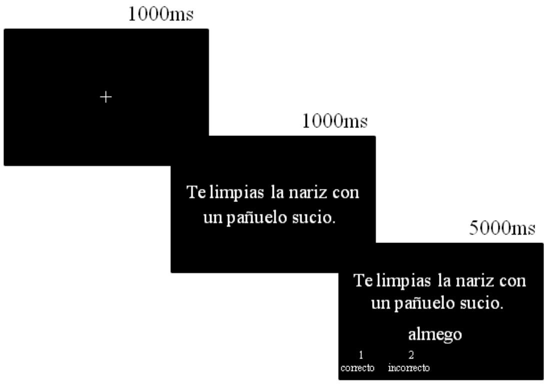
* The English translation of the sentence is "You clean your nose with a dirty handkerchief".

(B) Selection Test

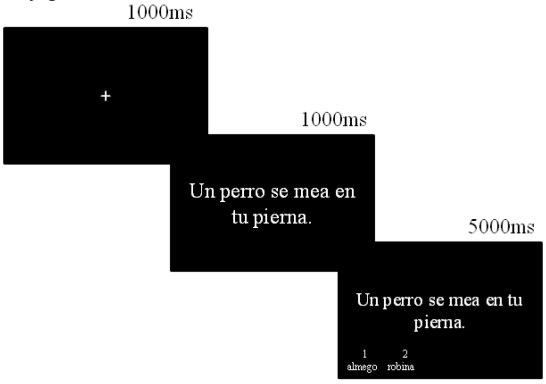


* The English translation of the sentence is "You clean your nose with a dirty handkerchief".

(C) Matching Test



(D) Within-modality generalization test



* The English translation of the sentence is "A dog pisses on your leg".

(E) Cross-modality generalization test

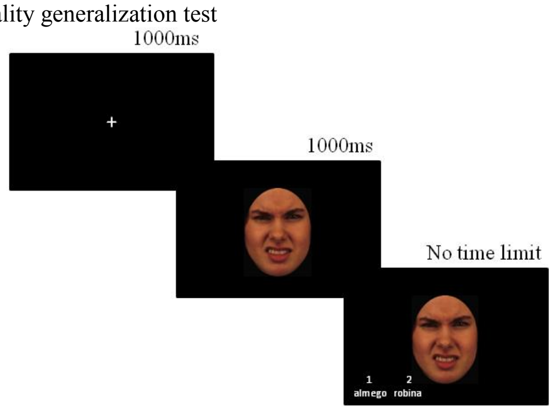


Figure 3. Examples of materials in the Sentence Group. The translation of the sentence in (A) and (B) is "You clean your nose with a dirty handkerchief", and in (C) is "A dog pisses on your leg".

Results

This section reports results related to the accuracy of responses to the generalization tests (within-modality and cross-modality tests), which are the most informative measures of meaning acquisition (see Figure 4 and Table 4). In the supplementary materials, we include additional accuracy statistics for the learning tests (pseudoword selection and pseudoword matching) and the response times of all the tests, which demonstrate no major difference in data analysis.

Table 4. Means and Standard Deviations of response accuracy (percentage) in the within- and the cross-modality generalization tests as a function of learning group and emotion.

	FACE GROUP		SENTENCE GROUP	
	Within-Modality	Cross-Modality	Within-Modality	Cross-Modality
EMOTION	%	%	%	%
disgust	86.50 (19)	84.50 (20)	81 (26)	73.20 (24)
sadness	67.50 (22)	79 (24)	77.10 (21)	79.50 (20)
neutral	79.50 (23)	80.50 (20)	66.80 (27)	66.80 (24)
overall	78 (17)	81 (16)	75 (18)	73 (16)

Within-Modality Generalization of the Two Groups

The mixed Group (2: sentence, face) and Emotion (3: sadness, disgust, and neutral) ANOVA on accuracy rate in the within-modality generalization tests yielded a main effect of emotion, F (2, 80) = 9.512, $p < .001$, $\eta^2 = .099$, but not of group, F (2, 80) = .525, $p = .471$, $\eta^2 = .007$. This emotion effect was qualified by the significant Group x Emotion interaction, F (2, 80) = 7.551, $p < .001$, $\eta^2 = .079$.

For the Face Group, post-hoc comparisons revealed that the accuracies for disgust and neutral trials were significantly higher than those for sadness, t (39) = 5.208, $p < .001$; t (39) = 3.674, $p < .001$. There was no significant difference between the accuracies of disgust and neutral trials, t (39) = 1.769, $p = .085$. In contrast, for the Sentence Group, accuracies were higher for the two emotion categories, disgust and sadness, than for the neutral category, t (40) = 2.916, $p = .006$. There was no significant difference between disgust and sadness trials, t (40) = .822, $p = .416$.

The comparisons across the two learning groups showed higher accuracy in the Face Group than in the Sentence Group, t (80) = 2.274, p = .026, for the neutral category. In contrast, there was no reliable difference between the learning groups for both disgust and sadness t (80) = 1.070, p = .288, t (80) = 1.969, p = .052, though for the latter there was a tendency for better performance in the Sentence group relative to the Face Group.

Cross-Modality Generalization of the Two Groups

The mixed ANOVA on accuracy rate revealed a main effect of group, F (2, 80) = 5.153, p = .026, η^2 = .061, but not of emotion, F (2, 80) = 2.213, p = .113, η^2 = .026. The accuracy in the Face Group was significantly higher than in the Sentence Group. This effect was qualified by the Group x Emotion interaction, F (2, 80) = 3.299, p = .039, η^2 = .039.

For the Face Group, there was no significant difference in accuracy among the three emotion categories, F (2, 39) = .979, p = .380, η^2 = .024. In contrast, for the Sentence Group, accuracy was higher for sadness than for the neutral category, t (40) = 3.329, p = .002, while there was no significant difference between disgust and sadness, t (40) = 1.525, p = .135, or between disgust and neutral, t (40) = 1.305, p = .199.

Finally, the comparisons across groups for each emotion revealed higher accuracy in the Face Group than in the Sentence Group for disgust, t (80) = 2.310, p = .024, and neutral, t (80) = 2.731, p = .008, while there was no significant difference between the two groups for sadness trials, t (80) = .103, p = .918.

General Comparison of Emotion Acquisitions

In order to explore emotion acquisition efficiency for the two stimulus modalities (faces and sentences), participants' performances over the same test stimuli were analyzed.

New Face Stimuli

This comparison analyzed participants' accuracy rates on new face stimuli, i.e., the within-modality generalization test for the Face Group and the cross-modality generalization test for the Sentence Group.

The mixed ANOVA on accuracy rate revealed a main effect of emotion, F (2, 80) = 3.547, p = .031, η^2 = .037, but not of group, F (2, 80) = 1.578, p = .213, η^2 = .020. This emotion effect was qualified by the significant Group x Emotion interaction, F (2, 80) = 13.109, p < .001, η^2 = .137. The accuracy rate in the Face Group was higher than in the Sentence Group for disgust and neutral faces, t (80) = 2.749, p = .007, t (80) = 2.392, p = .019. By contrast, the accuracy rate of sadness faces was significantly higher for the Sentence Group than for the Face Group, t (80) = 2.585, p = .012.

New Sentence Stimuli

This comparison analyzed participants' performances on sentence stimuli, which would be the cross-modality generalization test of the Face Group and the within-modality generalization test of the Sentence Group.

There was no significant difference between the two groups in accuracy rate, F (2, 80) = 2.171, p = .117, η^2 = .025.

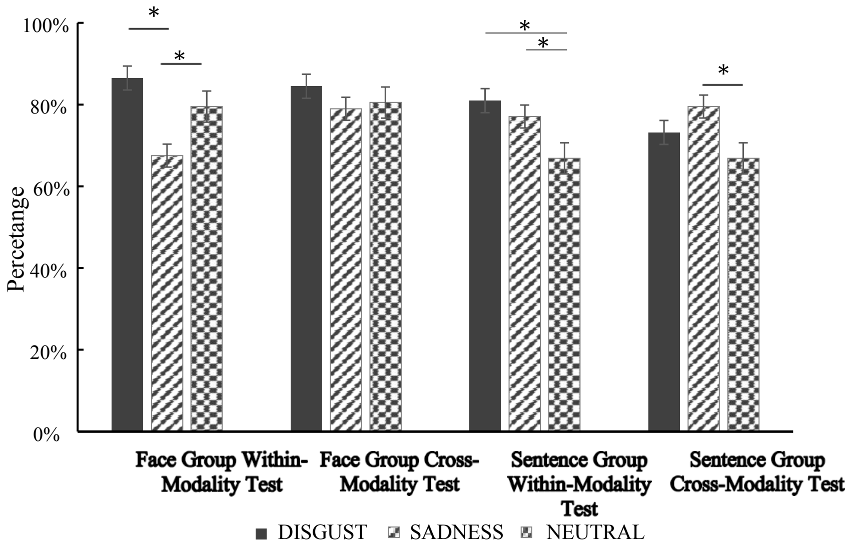


Figure 4. Means and Standard Errors of response accuracies (percentage) in the within- and the cross-modality generalization tests as a function of learning group and emotion. "*" means $p < .05$.

Discussion

The present study compared two different contexts for the acquisition of specific emotional meanings of written new words. Two groups of participants acquired disgusting, sad, and neutral connotations for pseudowords, by associating them either with faces or with sentences. Both groups performed well in the initial association tests, as shown in the supplementary materials, which confirmed that participants learned the associations between specific pseudowords and specific emotionally valenced stimuli. Critically, the two groups reached good performance in the within-modality generalization tests, with non-learned faces or sentences, indicating that the two associative contexts succeeded in inducing emotional meanings and serving as mediations to process new words (Kroll & Stewart, 1994). Still, the performances of the two groups were modulated by emotions. Participants in the Face Group tested with new faces performed better at new words associated with disgust and neutral stimuli than those associated with sadness stimuli, while participants in the Sentence Group tested with new sentences did better at new words associated with disgust and sadness stimuli than those associated with neutral stimuli. The two groups showed cross-modality generalization as well. Specifically, when the Face Group was tested with sentences, the participants performed equally well for the three emotional categories, whereas when the Sentence Group was tested with facial expressions, performance was better for new words associated with sadness stimuli. Comparison between the two groups demonstrated that the Face Group outperformed the Sentence Group at new words associated with disgust and neutral stimuli while, in some analyses, the Sentence Group did slightly better at new words associated with sadness stimuli than the Face Group. To sum up, the results suggested that 1) the learning was efficient for both learning groups; 2) the two groups manifested differences; and 3) the differences were dependent on the specific emotion involved.

The acquired emotional meanings of new words were categorial in two senses. Firstly, the emotional connotations of the new words generalized to new stimuli beyond those used in the Learning Phase. This generalization even extended to stimuli in a different modality than the learned stimuli. Secondly, the new words themselves had a categorial structure, as all the pseudowords associated with a given emotion had a distinctive orthographic pattern (e.g., for some participants, pseudowords starting with "al" could be associated with disgust), thus offering a proxy of real emotional words that are often organized as morphological sets with the same root (e.g., disgust, disgusting, disgusted).

Notably, both associative learning procedures were efficient for inducing emotional meaning, despite the different cognitive and neural processes presumably involved. Concerning the processing of facial expressions, previous studies have shown that emotions can be vicariously activated in oneself by observing other people's motor or vocal emotional expressions, relying on the mirror neuron system (Baumeister et al., 2017; Gallese et al., 2004; Niedenthal, 2007). Such an idea is further supported by studies investigating the first-person experience of disgust and the recognition of disgust in other people (Calder et al., 2000; Wicker et al., 2003). Therefore, pairing new words with emotional facial expressions, as we did with the Face Group procedure, likely results in establishing Hebbian associations (Hauk et al., 2004; Hebb, 1949) between the activation of face- related mirror neurons and the activation of neurons responsible for encoding the orthographic and phonological features for the co-occurrent pseudowords.

In contrast, the induced emotional meanings of new words in the Sentence Group relied on purely linguistic associative processes. Linguistic context plays a well-known role in learning word meaning (Bloom, 2000; Chaffin et al., 2001; Landauer & Dumais, 1997; Lindsay & Gaskell, 2010; Nagy et al., 1987). For instance, word co-occurrence is exploited by readers to learn the meaning of low-frequency and abstract words that cannot be easily associated with perceptual experiences (Landauer & Dumais, 1997; Mestres- Missé, 2008). Linguistic context can be especially relevant to learn emotional vocabulary, given the fact that some social or introspective emotions (e.g., jealousy, envy, frustration) do not involve distinctive facial or body expressions and learning their corresponding labels may require verbal descriptions or narratives (Aragão, 2011).

Above all, which learning protocol was more efficient, the face or the sentence association? The Face Group demonstrated a general advantage in acquiring disgust and neutral meanings for new words in comparison to the Sentence Group. The pseudoword-face associative procedure seemed especially efficient in acquiring disgusting connotations, probably because of the extremely distinctive expression for this emotion, which might trigger the disgust-related mirror neuron system, as previous studies have demonstrated (Gallese et al., 2004; Wicker et al., 2003). Another explanation, suggested by studies on second language embodiment, is that bilinguals are able to simulate actions and emotions when they process words in their second languages (Baumeister et al., 2017; Dudschig et al., 2014; Macedonia, 2015; Pasfield-Neofitou et al., 2015; Sheikh & Titone, 2016). In the present study, faces served as more concrete and straightforward materials for acquiring emotional connotations for new words. Given the fact that disgust is associated with distinctive facial expressions (Rozin et al., 1994), the embodiment effect could contribute to the participants' performance in the evaluation tests. As for the Sentence Group, participants performed well, being able to use the new words to match new sentences sharing the same emotional category (within-modality generalization), but these participants were not as efficient when encountering faces (cross-modality generalization). Such patterns suggest that the sentences used for disgust acquisition had successfully induced the intended emotion, reflected by the higher accuracy in the within-modality test. However, the lower accuracies for the cross-modality test suggest that the acquisition is scenario-based and less categorial.

Another advantage of the Face Group over the Sentence Group was its participants' better performance with emotionally neutral stimuli. Neutral stimuli have been commonly used as a control or baseline condition in studies of emotional facial expressions (Phan et al., 2002; Wager & Smith, 2003) and emotional words (Fields & Kuperberg, 2012). Though some previous studies have indicated that neutral faces may be evaluated as negative in some circumstances (Lee et al., 2008), participants in our Face Group did not confuse neutral faces with disgust or sadness during acquisition, as their high accuracy in the generalization tests demonstrated. However, the performance of the Sentence Group for neutral trials in both the within-modality and cross- modality tests was significantly worse, which could be attributed to the difficulty of maintaining the neutrality of the sentences during acquisition. Though the sentences were rated as neutral in the normative study, they were prone to be contaminated by individual differences or participants' personal experiences. For example, if the participant was late for class due to a delay of the tram, the sentence "You go to school by tram" might gain a negative valence.

Although the Face Group showed significant advantages over the Sentence Group on disgust and neutral trials, the two groups' performance on sadness trials was similar for the generalization tests. Sad facial expressions have raised some controversies in previous studies (Fernández- Dols & Crivelli, 2013; Reisenzein et al., 2013). Prototypical facial expressions of sadness are not always observed when people experience sadness as an internal state under non-social circumstances (Namba et al., 2017). Therefore, the ambiguity of the sad facial expressions might cause confusion for participants in the Face Group when they encountered new faces, especially along with another negative emotion. However, for participants in the Sentence Group, the new faces were introduced as stimuli of another modality that carried social values. These factors simplified the difficult task of decoding the faces. Nevertheless, the Face Group did well at sadness trials in the cross-modality test, that is, generalization to sentences, indicating successful emotion acquisition.

Some limitations are worth noting. Firstly, the study demonstrated strong associative learning of emotional connotations for new words but did not test whether these acquired meanings play a lexical role in linguistic contexts, such as being integrated at the sentence or the discourse level. For instance, once the association of "robinado" with sadness had been learned, would the participant understand the sentence "John's dog died in his arms and he felt robinado"? Secondly, in future experiments, it will be worth investigating the neural signatures of the new words' acquired meanings, comparing them to those of real words to verify the extent to which the lexicalization process is implemented in the brain (Fernández-Dols & Crivelli, 2013; Reisenzein et al., 2013).

Conclusion

The present study compared the efficiencies of two associative contexts in emotional meaning acquisition of written words: faces and sentences. Post- acquisition tests suggested that faces are more effective for learning disgust and neutral emotions, while sentences are slightly more advantageous for learning sadness. However, the advantage of sentences in learning sadness was only manifested when the words were generalized to describe faces. Taken together, facial expressions, as the first accessible channel for humans to acquire emotions, are found to be more effective than emotional sentences for acquiring emotional meanings for written words.

EXPERIMENT 3[5]

ERP signatures of new words acquired emotional connotation of disgust and sadness

Abstract: The present study investigated how two negative yet distinctive acquired emotional connotations, disgust and sadness, affect the neural activity in word processing. Participants completed a learning session in which pseudowords were repeatedly paired with faces expressing disgust, sadness, and neutrality. The learning session was followed by an event-related potential recording session on the next day, in which the participants received the learned pseudowords (herein, new words), mixed with new pseudowords, real words, and vehicle names with instructions to press a key only for the latter. Sad new words reduced the early posterior negativity (EPN) amplitudes compared to disgust and neutral new words in the time window of 206 – 242 ms, while disgusting new words reduced the amplitude of the late positive complex (LPC) compared with neutral new words in the time window of 400 – 500 ms. Importantly, the source localization in the EPN time window perfectly dissociated the three emotional conditions: disgusting new words elicited the largest activation in the right insular cortex, sad new words elicited more activity in the right anterior cingulate cortex, and neutral new words increased activations in the facial expression area in the occipital lobe. These results suggested that faces are an effective source for the acquisition of words' emotional connotation, which also revealed distinctive neural signatures.

[5] Based on the results of Experiment 3, a paper has been written is ready for submission.

Keywords: disgust; sadness; pseudowords; faces; ERPs

Introduction

Emotional connotations are important features of word meaning (Taylor et al., 2013). Although numerous studies have explored the brain dynamics of emotional word processing in various languages, only a few of them examined how acquired emotional valence of words (Hebb, 1949) modulate neural activity, generally finding differential modulations in early and late ERP components However, these studies on the acquisition of words' emotional connotations only reflected a gross distinction between positive and negative valences, which does not represent the rich variety of emotional nuances conveyed by real-life emotional words. For instance, words like 'vomit' and 'failure' share a negative valence yet involve very different emotions. The present study, like the previous ones, used an associative learning paradigm to induce emotional meaning in written new words, but it focused for the first time on two specific negative emotions, disgust and sadness, aiming at finding differential neural signatures for them rather than examining general valence effects.

Disgust is one of the six basic emotions proposed by Ekman (Fargier et al., 2012; Liuzzi et al., 2010; Pulvermüller, 2005), which is induced by aversive stimuli in relation to contamination or disease (Taylor et al., 2013). Disgust is an emotion highly relevant to our well-being as it protects us from being harmed by noxious substances by encouraging withdrawal behaviors (Hebb, 1949). Such withdrawal behaviors usually come with a variety of psychophysiological responses such as nausea, reduced heart rate, amplified skin conductance, and decreased respiratory rate (Fargier et al., 2012; Liuzzi et al., 2010; Pulvermüller, 2005). Results of brain imaging studies of lesions (Taylor et al., 2013) and healthy participants (Hebb, 1949) showed that the anterior insula is likely to be the main brain structure involved in processing disgust in various modalities.

Sadness, on the other hand, also being one of the six basic emotions, is associated with failure (Fargier et al., 2012; Liuzzi et al., 2010; Pulvermüller, 2005) and loss (Carver, 2004; Lench et al., 2011; Levine & Pizarro, 2004), both in social and non-social situations (Keltner & Kring, 1998). It could serve as a biological reaction that helps individuals maintain group attachment (Bolby, 1980) and expresses a need for change that may elicit empathy (Kreibig et al., 2007). Previous studies suggested that sadness elicits increased diastolic blood pressure (Krumhansl, 1997; Sinha et al., 1992) and nonspecific skin conductance (Frazier et al., 2004) and decreased ear pulse amplitude and finger skin temperature (Gross & Levenson, 1997; Kreibig et al., 2007; Krumhansl, 1997; Kunzmann & Grühn, 2005). Previous studies have demonstrated that there are multiple brain structures in relation to sadness processing (Lane et al., 1997) but most recent ones have yielded more converging results that anterior cingulate cortex is associated with and mediates sadness-related experience (Niida & Mimura, 2017; Ramirez-Mahaluf et al., 2018; Webb et al., 2018).

In this study, we chose disgust and sadness as the emotions of interest for several reasons. First of all, rather than investigating the differences between new words' acquired valences as in previous studies (Bayer et al., 2019; Kulke et al., 2019), we intended to narrow the research scope to analyze fine-grained differences in neural dynamics for two specific negative-valence emotions. Secondly, we were particularly interested in studying disgust, an emotion that is highly relevant to humans' well-being as stated above yet relatively neglected in emotional language studies. Thirdly, sadness was chosen as the contrasting emotion to disgust because both of them possess distinctive features: disgust is more urgently triggered by external physical stimuli (Rozin & Haidt, 2013) whereas sadness is a more passive, internal, and psychosocial emotion (Kreibig et al., 2007; Mikulincer & Florian, 1997). Other negatively valenced emotions, such as fear and anger, are also highly distinctive and easy to identify (Adolphs et al., 1999; Mattavelli et al., 2014). However, both of them are generally triggered by threatening stimuli (Spielberger & Reheiser, 2010) similar to disgust yet disgust manifested different behavioral and ERP patterns in attentional modulation than fear and anger (Zhang et al., 2017) while sadness is different in that it is the reaction to the loss of valuable goals or significant others (Lench et al., 2011) and social rejection (Izard & Buechler, 1980). In addition to the two negative emotions, the neutral condition was introduced as a control baseline for a general emotional effect.

In the present study, participants acquired emotional connotations for pseudowords by pairing them with faces expressing disgust, sadness, and neutrality. This is a main novelty with respect to other associative learning paradigms that typically use pictures or videos to induce the acquisition of emotional connotations in words or pseudowords. Facial expressions are effective channels (Darwin, 1872) for communication and expressing emotions (Paul Ekman, 1992a, 1993; Russell et al., 2003). They also serve as the first source for children to acquire emotional concepts when children interact with their caregivers (Denham, 1998; Izard, 1971). Previous studies have demonstrated that words' emotional connotations and facial expressions are strongly associated in semantic memories (Baggott et al., 2011; Beall & Herbert, 2008; Kar et al., 2018; Stenberg et al., 1998). Such association was found in the second language as well. Experimental evidence suggested that processing emotional words in the second language induces word-face conflicts in Stroop tasks (Fan et al., 2016, 2018) and specific face muscles involved in processing certain emotions were triggered during emotional words processing in the second language (Foroni, 2015), even in late bilinguals (Baumeister et al., 2017), although such effects were not as strong as in the first language (Kroll & Stewart, 1994; Opitz & Degner, 2012; Pavlenko, 2012). In face-to-face communication scenarios, emotions could be recognized through other people's facial expressions and words associated with emotional states and events (Lundqvist et al., 1998). Regarding the two emotions concerned here, feeling disgusted is associated with nose wrinkle, gape, tongue extrusion, and raised upper lips (Rozin et al., 1994) whereas feeling sad involves lowered mouth corners and raised inner portion of the brows (Ekman et al., 2002).

Measuring event-related potentials (ERPs) is an effective way to investigate the influence of acquired emotional connotations on word processing. Previous studies have provided vast evidence that ERPs are sensitive to emotional features of words in both early and late time windows (Citron, 2012; Herbert et al., 2008; Kanske & Kotz, 2007; Kissler et al., 2007, 2009; Yi et al., 2015; Zhang et al., 2014). For early ERP components, the most commonly reported modulation of emotion is the early posterior negativity (EPN). It is a negative-going component that mainly occurs over temporo-occipital electrodes, which peaks between 200 to 300 ms after stimulus onset. There is extensive evidence suggesting that the EPN component is modulated by emotion-related factors such as attentional resources used in emotional perception and emotional arousal (Junghofer et al., 2001; Schupp et al., 2004a; Schupp et al., 2004b). However, such modulations were independent of experimental tasks (Herbert et al., 2011; Kissler et al., 2006; Schacht & Sommer, 2009a). The EPN component can also be associated with lexical access (Citron, 2012), which has been commonly reported in studies on emotional words processing (Franken et al., 2009; Herbert et al., 2008; Palazova et al., 2011; Scott et al., 2009). More specifically, Ponz and colleagues (2014) found larger EPN amplitudes for disgust-related word processing compared with neutral words.

In the late time window, the late positive complex (LPC), or late posterior positivity (LPP), which peaks between 400 – 800 ms, is highly relevant to emotional words processing. It is a component sensitive to words' valence and indexing sustained and deep processing of the words' semantic and emotional connotations (Carretié et al., 2008; Hinojosa et al., 2010; Kanske & Kotz, 2007; Kutas & Federmeier, 2000; Schacht & Sommer, 2009a). Numerous previous studies have reported enhanced LPC amplitudes for negative words than neutral words (Gootjes et al., 2011; Hofmann et al., 2009; Kanske & Kotz, 2007; Schacht & Sommer, 2009b). Such emotional enhancement of LPC was also found in the comparison between disgust-related and neutral words (Ponz et al., 2014). However, there was also evidence demonstrating larger LPC amplitudes for neutral words than emotionally-valenced words (Citron et al., 2011; Hinojosa et al., 2009). Compared with EPN, LPC represents more controlled and explicit processing of words' emotional connotations (Citron, 2012).

This study used faces with disgusting, sad, and neutral expressions to endow written pseudowords with emotional connotations and to examine the neural signatures of such acquired emotional connotations. Participants first completed a learning session, in which they were exposed to the pseudowords repeatedly paired with the faces in three learning blocks. After each block, participants went through a test that was designed to probe their learning of the pairings. When the learning phase was completed, participants continued to the evaluation phase, consisting of three tests to further examine their learning of the pairings and the acquisition of emotional connotations. The ERP recording session was conducted the next day after the learning session for each participant. A simple Go/NoGo lexical-semantic decision task was employed in which participants were instructed to make responses only to vehicle names. Therefore, the emotional connotations of pseudowords were processed implicitly. We hypothesized that as a more alerting and externally induced emotion that draws more attention, disgust would elicit the largest EPN amplitudes in words processing among the three emotional conditions and sadness the smallest since it is more passive and internally generated. On the other hand, neutrality, being the only non-valenced condition in the current experiment, might require more sustained attention and evaluation to be successfully processed (Citron, 2012) compared with the two negative emotions and thus elicit the largest LPC amplitudes in the late time window. On the contrary, we expected that disgust would elicit the smallest LPC amplitudes for its salient nature. Regarding brain activations, we hypothesized that the insular cortex would be more active during the processing of disgusting connotations and processing sad connotations would induce more activations in the anterior cingulate cortex.

Material and Methods

Participants

Twenty-nine Spanish college students (4 males) were recruited as participants for the experiment, who are all native speakers of Spanish, with ages ranging from 20 to 22, all right-handed, with normal or corrected to normal vision and no history of psychiatric or neurological disorders. All participants participated voluntarily in the experiment and were rewarded with course credit for the learning session and money (5 euros) for the ERP recording session. One participant was excluded due to excessive artifacts in the ERP data.

Material[6]

For the learning session, 30 pseudowords of 8-9 letters were composed, one third of which (10) started with the syllable "al", "ro" or "le" respectively. Forty-five faces

[6] The whole set of materials of Experiment 3 is reported in Appendix 6, at the end of the thesis

expressing disgusting, sad, and neutral emotionality were selected from the KDEF (Lundqvist et al., 1998) stimuli set (disgust: F02, F03, F09, F12, F13, F16, F22, F35, M12, M14, M18, M22, M24, M25, M31; sadness: F05, F09, F11, F13, F14, F20, F22, F31, M05, M11, M13, M14, M25, M31, M35; neutral: F01, F03, F05, F07, F13, F19, F26, F29, M06, M08, M10, M11, M13, M31, M35). Table 1 shows the hit rates of intended emotions and the arousal values of the faces obtained from the KDEF documents (Karolinska Directed Emotional Faces (KDEF) documents — Department of Experimental Clinical and Health Psychology — Ghent University). There was no significant difference in hit rates among the three categories of emotions, F (2, 28) = 1.896, p = .169, η^2_p = .119. Regarding arousal, there were significant differences among the three categories of emotions, F (2, 28) = 40.812, p < .001, η^2_p = .745. Post-hoc tests suggested that disgust and sadness faces were significantly more arousing than neutral faces, p < .001, but no significant arousal difference was found between disgust and sadness, p = .211. Non-facial areas (e.g. hair) were removed by applying an ellipsoidal mask. The faces were presented against a black background with each face being 11.5 cm high by 8.5 cm wide, which equals a visual angle of 9.40° (vertical) × 6.95° (horizontal) at 70-cm viewing distance.

In addition, 15 sentences expressing the three emotions (5 in each emotion category) were composed for the cross-modality generalization test in the evaluation phase. Two groups of students of the same college population who did not participate in the final experiment rated the emotions expressed by the sentences (39 participants) and their arousal (32 participants) through online questionnaires. For the emotion expressed, participants were instructed to choose the emotion (neutral, sadness, happiness, disgust, or anger) that better fits the emotion connoted by the sentences, and to rate their choice confidence on a 5-point scale (1-a little sure, 5-completely sure). For arousal, participants were asked to rate the arousal of the sentences in a different questionnaire, over a 5-point scale (1-very peaceful, 5-very exciting) (see Table 2). There was no significant difference in hit rates among the three categories of emotions, F (2, 8) = .209, p = .816, η^2_p = .05, nor confidence scores, F (2, 8) = 2.057, p = .19, η^2_p = .34. There were significant differences in arousal among the three categories of emotions, F (2, 8) = 54.041, p < .001, η^2_p = .931. Post-hoc tests suggested that disgust and sadness sentences were significantly more arousing than neutral sentences, p = .004, p < .001, respectively. There was no significant difference between disgust and sadness, p = .916.

For the ERP recording session, in addition to the 30 pseudowords, 10 new pseudowords starting with "bi" were introduced as a control baseline for demonstrating the learning effects. In addition, 20 real neutral words were included in the experiment to ensure participants' semantic processing of the stimuli and serve as a baseline for demonstrating the lexicalization effects. Finally, 20 vehicle names were included in the ERP recording session for participants to make responses.

Table 1. Means and Standard Deviations of the hit rates of intended emotions (percentage) and arousals of the KDEF faces used in the experiment.

	HIT RATES	**AROUSAL**
EMOTION	%	
disgust	91.87 (9)	3.75 (0.5)
sadness	91.66 (7)	3.43 (0.4)
neutral	87.69 (5)	2.46 (0.2)
overall	90.41 (7)	3.21 (0.3)

Table 2. Means and Standard Deviations of the hit rates of intended emotions (percentage), choice confidence scores, and arousal of the sentences used in the experiment.

	HIT RATES	CHOICE CONFIDENCE SCORES	AROUSAL
EMOTION	%		
disgust	80.51 (3)	4.48 (0.2)	4.15 (0.4)
sadness	81.02 (4)	4.49 (0.2)	4.12 (0.5)
neutral	81.03 (5)	4.28 (0.1)	2.07 (0.4)
overall	80.86 (4)	4.42 (0.2)	3.45 (0.4)

Design and Procedure

Learning session. This session included a training phase, an evaluation phase, and a generalization phase. Figure 1 depicts the sequence and timing of the events in each kind of trial. Each training trial began with a fixation cross at the center of the screen, followed by the face alone, and them the pseudoword (in Times New Roman font, size 50) overlapping the face. There were three training blocks with four face-pseudoword pairs of each emotion in the first block and three pairs in the second and third. Each pair was repeated six times within each block and thus, there were 72, 54, and 54 training trials in the first, second, and third block respectively. The assignment of pseudowords to emotions was counterbalanced across participants. After each training block, there was a pseudoword selection test that evaluates participants' learning. The test trials began with a fixation cross, followed by one of the faces presented in the training phased and then two pseudowords of the preceding learning block appeared at the lower-left corner of the screen (in Times New Roman font, size 18). Participants were instructed to select which pseudoword has been presented with the face on the screen in the previous training block by pressing "1" on the keyboard for the one on the left and "2" for the one on the right (not the keypad) with their left hands.

The evaluation phase began after participants completed all three training blocks. The first test in this phase was a pseudoword matching test. The 30 trials in this test were presented in the following sequence: a fixation cross followed by a face from the three training blocks, and then a pseudoword over the face with two options of "correct" and "incorrect" at the lower-left corner of the screen. Participants were required to judge whether the pairing between the pseudoword and the face was correct according to their learning during the training phase by pressing "1" on the keyboard for "correct" and "2" for "incorrect". The font and font sizes here were identical to those in the pseudoword selection test.

The next two tests, the within-modality generalization test, and cross-modality generalization tests, were designed to go beyond simply testing participants' learning of specific pairings between pseudowords and faces but to investigate whether the learned pseudowords acquired emotional connotations that generalize to new stimuli. The 15 trials in the within-generalization test proceeded in the same sequence as the pseudoword selection test, except that here two learned pseudowords were presented with a new face that was not presented in the training phase but also expresses one of the three emotions. Participants were asked to select among the two pseudowords the one that best describes the emotion expressed by the new face by pressing "1" or "2" on the keyboard as in the pseudoword selection test. Finally, participants were required to complete the cross-generalization test, which introduces sentences expressing the three emotions rather than faces. The 15 test trials began with a fixation cross followed by a sentence at the center of the screen (Times News Roman font, size 30). Two learned pseudowords were then presented at the lower-left corner of the screen. Participants were instructed to select which pseudoword best describes the emotion expressed by the sentence by pressing “1” or “2” on the keyboard as in the previous test. There was no time limit for responses here since it was more demanding than the previous tests. In all four tests, participants received immediate feedback after their responses indicating whether they have made the right choice or not.

EEG session. The EEG recording session was conducted on the next day after participants completed the learning session. Participants first completed a refreshment task of what they have learned on the previous day in which they went through all four tests in the preceding learning session. After that, they were seated comfortably in a chair in a sound-attenuated room. Stimuli were presented on a computer monitor with E-Prime software about 80 cm away from participants. The task of the experiment was to silently read each presented stimulus carefully. When the stimulus presented was a vehicle name, participants were asked to press a button “1” on the gamepad as quickly as possible. Otherwise, they were instructed to stay put. Each participant read 30 learned pseudowords, 10 new pseudowords, 20 real words, and 20 vehicle names during the experiment and all stimuli were repeated three times, resulting in 240 experimental trials. Each trial began with a fixation cross presented for 500 ms in white color against a black background in Times New Roman font, size 36, followed by the stimulus presented in the same color, font, and size for 1000 ms. Participants responded during the presentation of the stimulus. Next, a 500 ms blank screen was presented followed by a 2500 ms rest signal (Figure 2). Before the experimental started, participants first completed 20 practice trials to get familiar with the experimental procedure.

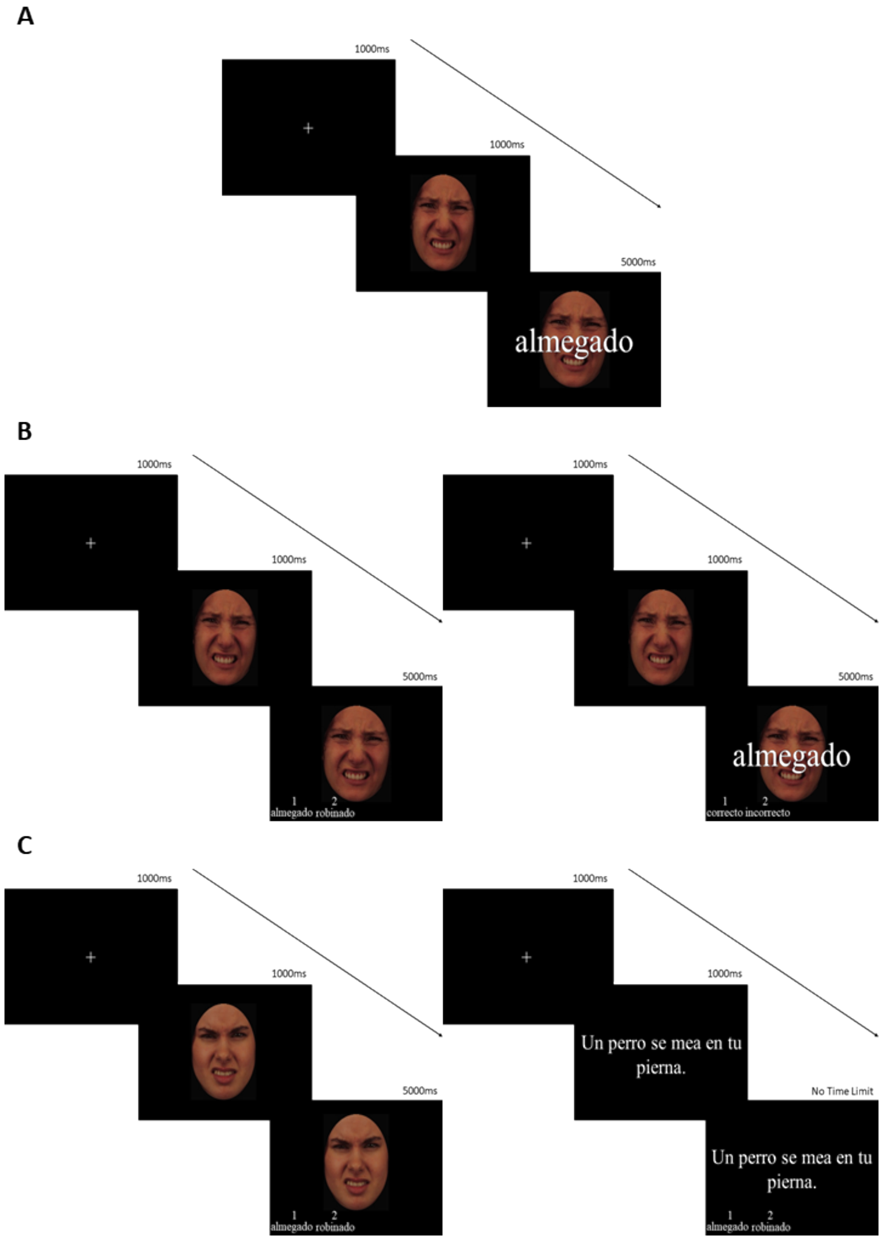

A
1000ms
+
1000ms
5000ms
almegado
B
1000ms
+
1000ms
5000ms
1 2
almegado robinado
1000ms
+
1000ms
5000ms
almegado
1 2
correcto incorrecto
C
1000ms
+
1000ms
5000ms
1 2
almegado robinado
1000ms
+
1000ms
Un perro se mea en tu pierna.
No Time Limit
Un perro se mea en tu pierna.
1 2
almegado robinado

Figure 1. Outline of trials in the learning session. (A) Training trial. (B) Pseudoword selection test trial (left) and pseudoword matching test trial (right). (C) Within-modality generalization test trial (left) and cross-modality generalization test trial (right).

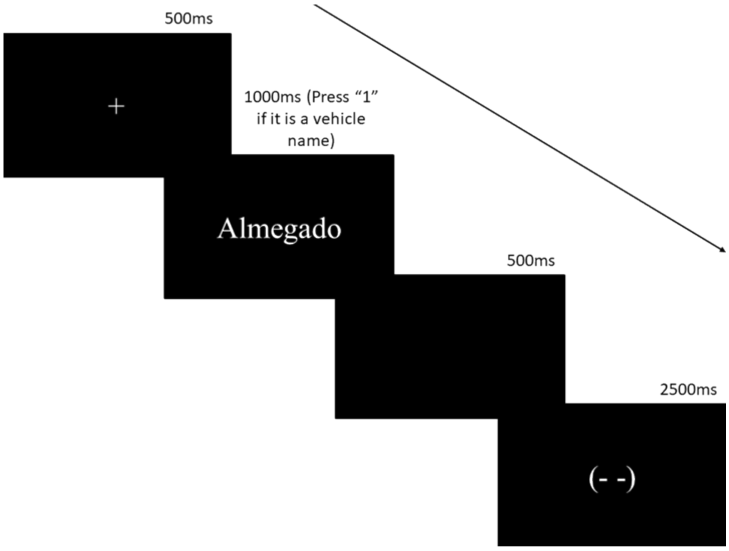


Figure 2. Outline of a trial in the ERP recording session.

EEG Recording and Analysis

Electroencephalography (EEG) and electrooculography (EOG) data were recorded with Ag/AgCl electrodes mounted in elastic Quick-caps (Compumedics). EOG data were recorded from two bipolar channels: one from two electrodes placed at the outer canthus of each eye and the other from two electrodes above and below the left eye. EEG data were recorded from 60 electrodes arranged in accordance with the standard 10 – 20 system with additional electrodes placed on the left and right mastoids (M1 & M2). All electrodes were re-referenced offline to the left and right mastoids. EEG and EOG signals were amplified at 500 Hz sampling rate using Synamp2 amplifier (Neuroscan; Compumedics), with high- and low-pass filters set at 0.05 and 50 Hz respectively. The impedances of the electrodes were kept at under 5 k Ω. The ERP recordings were time-locked to the onset of each stimulus and ERP analysis was applied to an epoch extending from 200 ms before to 1000 ms after the stimulus onset. The preprocessing and analysis of the EEG data were conducted using Brainstorm (Gramfort et al., 2010). Experimental trials with drifting, ocular, or motor artifacts were rejected by visual inspections before analysis. Eye blinks and movements were further removed by applying the Independent Component Analysis (ICA). Next, trials with EEG voltages exceeding 70 μV measured from peak to peak at any channel were removed.

ERP were computed and analyzed with Brainstorm as well. The 200 ms period before the stimulus onset was used as the baseline. Then, ERP waveforms were obtained by averaging baseline-corrected EEG segments in five conditions: disgust pseudowords, sadness pseudowords, neutral pseudowords, new pseudowords, and real words. Massive pairwise t-tests were conducted between every two conditions to find ERP time windows of interest. Next, the ERP amplitudes of relevant conditions were averaged within those specific time windows to identify electrodes showing significant differences. Finally, statistical data of the electrodes in specific time windows were exported to run one-way, repeated measures ANOVAs with emotions (disgust, sadness, and neutral) as within-subjects factors.

Source Localization Analysis

Source localization was conducted using Brainstorm and EEG data were co-registered with a standard anatomical template (ICBM152) and boundary element head models were constructed with OpenMEEG (Pascual-Marqui, 2002). Source activities were estimated for each emotion condition using sLORETA (Pascual-Marqui, 2002) with unconstrained source orientations. Differences between every two conditions were calculated for each participant and ROIs were created accordingly for sets of neighboring solution points showing significant differences ($p < .05$). Mean absolute values of the current densities of the ROIs were then exported for running ANOVAs as in the EEG data analysis.

Results

Behavioral Results

Learning Session

In this section, we focused on the results of accuracy of the two generalization tests (within- and cross-modality generalization tests) as they are the most informative measures of emotional meaning acquisitions for the pseudowords (see Table 3).

The mean response accuracy for disgusting, sad, and neutral trials in the within-modality test and in the cross-modality generalization test are shown in Table 3. Response accuracy did not differ significantly among the three categories of emotions in the within-modality (F (2, 54) = .862, p = .428, η^2_p = .031) or in the cross-modality generalization test (F (2, 54) = 2.932, p = .062, η^2_p = .098).

Table 3. Means and Standard Deviations of response accuracy (percentage of correct choices) in the within- and the cross-modality generalization tests.

	Within-Modality	Cross-Modality
Emotion	%	%
disgust	88.57(13)	95.71(8)
sadness	82.86(23)	85.00(22)
neutral	84.29(18)	87.86(21)
overall	85.24(18)	89.52(17)

ERP Recording Session

The mean accuracy for the vehicle name decision task was 86.43% (SD = 5.49%) and the mean response time was 577.23 ms (SD = 61.21). The rate of false alarms was 2.27% (SD = 2.87%).

ERP Results

Since the present study was focusing on the emotion acquisition effect, only results of comparisons among the three emotional categories of learned new words were presented here. Nonetheless, additional analyses of the learning effect (contrasting learned new words vs. unlearned new words) were reported in the supplementary materials[7]. The cluster-based random permutation method was used to find significant clusters in the time window of 0 – 1000 ms by comparing disgusting trials and sad trials, disgusting trials and neutral trials, and sad and neutral trials. The cluster time windows were determined by collapsing time windows where significant differences were found

[7] See Appendix 7 at the end of the thesis

in each comparison. Then each comparison was averaged to identify electrodes showing significant differences. Finally, clusters were established based on electrodes showing significant differences in all three comparisons. In this way, two clusters were identified with the first one extending exclusively from 206 – 242 ms and the second 400 – 500 ms (Figure 3 & 4). The ERP data for each condition for each time window were thus exported to perform further analyses.

Early Time Window (206 – 242 ms)

Figure 3 illustrated the waveform and topography of the significant effects of emotion for the early time window: F (2, 54) = 7.051, p = .002, η^2_p = .207. Post-hoc tests indicated that disgusting and neutral new words elicited larger negativity in right posterior electrodes than sad new words (p = .002 and p = .009, respectively). There was no significant difference between disgusting and neutral new words (p = .82).

Late Time Window (400 – 500 ms)

Figure 4 showed the waveform and topography of the significant effects of emotion for the late time window: F (2, 54) = 3.710, p = .031, η^2_p= .121. According to the Post-hoc tests, neutral new words elicited larger positivity in central and right posterior electrodes than disgusting new words, p = .023, while no significant difference was found between disgusting and sad trials, p = .134, nor sad and neutral trials, p = .396.

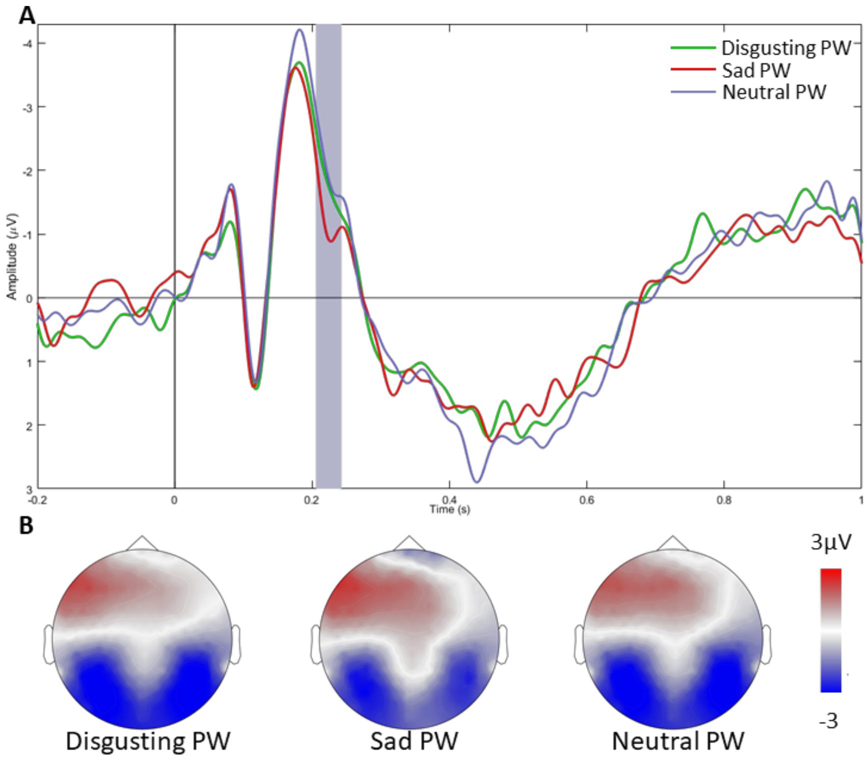


Figure 3. ERP results in the early time window (206 – 242 ms). (A) Average waveforms of disgusting new words, sad new words, and neutral new words in a cluster of electrodes manifesting significant differences (CP2, CP4, CP6, PZ, P2, P4, P6, P8, PO4, PO6, PO8, O2). (B) Topographical distributions of the EPN component for disgusting new words, sad new words, and neutral new words.

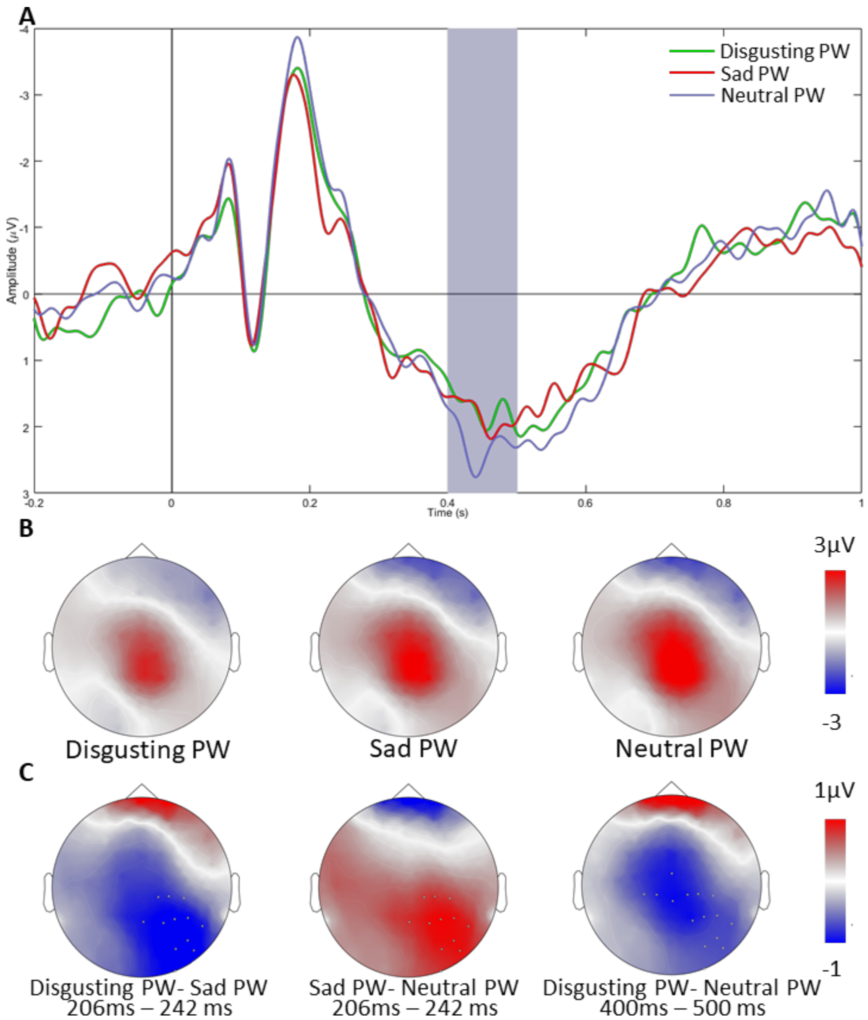


Figure 4. ERP results in the late time window (400 – 500 ms). (A) Average waveforms of disgusting pseudowords, sad pseudowords, and neutral pseudowords in a cluster of electrodes manifesting significant differences (CP3, CP1, CPZ, CP2, CP4, CP6, P2, P4, P6, P8, PO4, PO6, PO8, O2). (B) Topographical distributions of the LPC component for disgusting new words, sad new words, and neutral new words. (C) Differences between disgusting new words and sad new words and sad new words and neutral new words in the EPN component, and disgusting new words and neutral new words in the LPC component. The dots represent electrodes with significant difference.

Source Localization

Source localization for the ERPs identified above was conducted using sLORETA in Brainstorm. The analysis for the late time window failed to reach a converging result but three ROIs were identified in the medial orbitofrontal extending to the rostral anterior cingulate cortices, F (2, 54) = 6.325, p = .003, η^2_p = .19, in the insular cortex extending to the supramarginal gyrus and the superior temporal gyrus, F (2, 54) = 7.057, p = .002, η^2_p = .207, and in the lingual gyrus extending to the fusiform gyrus and the lateral occipital cortex, F (2, 54) = 6.950, p = .002, η^2_p = .205, during the early time window (Figure 5). Post-hoc tests showed that disgusting new words elicited larger current densities than sad new words in the insular cortex & supramarginal gyrus & superior temporal gyrus, p = .002, and lingual gyrus & fusiform gyrus & lateral occipital cortex, p = .003. However, current densities for sad new words were larger than for disgusting new words in medial orbitofrontal & rostral anterior cingulate cortices, p = .002. Finally, neutral trials elicited larger current densities than sad trials in lingual gyrus & fusiform gyrus & lateral occipital cortex, p = .03.

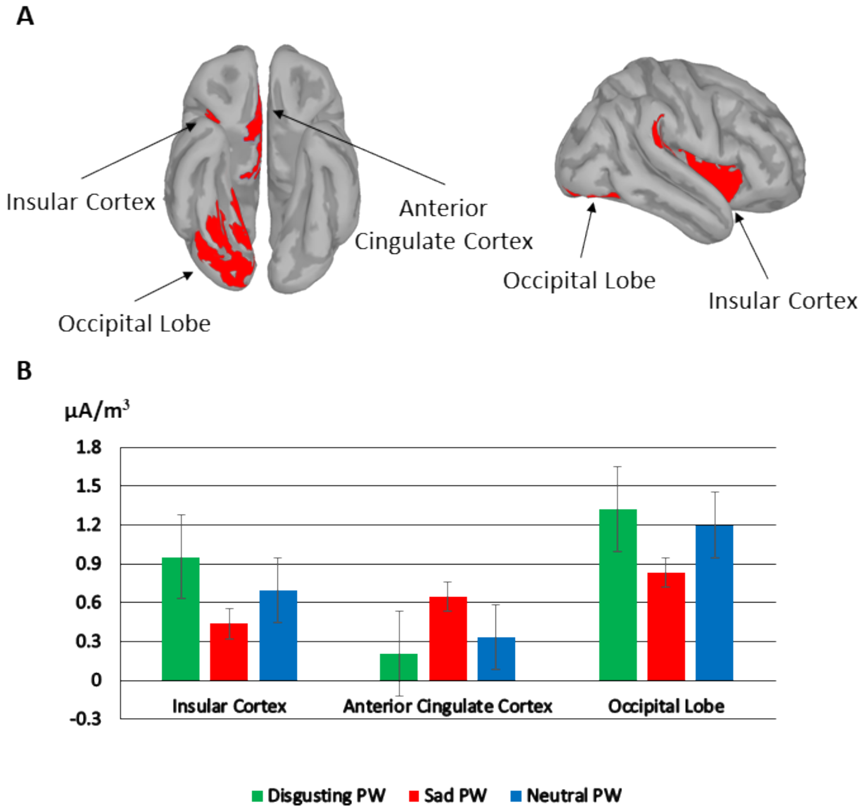


Figure 5. Source localization results corresponding to the ERPs in the early time window of 206 ms – 242 ms. (A) The cortices demonstrating the three ROIs: the insular cortex, the anterior cingulate cortex, and the occipital lobe. (B) Mean current densities for disgusting new, sad, and neutral new words in the three ROIs.

Discussion

The present study investigated the brain spatiotemporal dynamics associated with written new words, which acquired emotional connotations of disgust, sadness (or neutral) in an initial learning session by pairing them with faces. In the main EEG session, the emotional new words along with unlearned pseudowords, real words, and vehicle names were presented in a Go/NoGo decision task while participants' electrocortical activities were recorded. The results showed that facial expressions are effective to induce emotional connotations in new words, confirming previous behavioral results (Gu et al., in press). Most importantly, the ERP data revealed differential brain signatures for new words associated with the target emotions of disgust and sadness compared to neutrality. In the early time window of 206 – 242 ms, sad new words reduced the EPN amplitudes compared to disgusting and neutral new words. Differences were also found in a late time window of 400 – 500 ms where disgusting new words elicited larger positivity than neutral new words. Remarkably, the source analysis in the early time window, clearly dissociated the neural activities of the specific emotions. That is, disgusting new words elicited more robust activations than sad new words in the insular cortex, a region typically associated with disgust, as well as in the supramarginal gyrus and the superior temporal gyrus. By contrast, sad new words elicited more activities than disgusting new words in the medial orbitofrontal and the rostral anterior cingulate cortices, which are frequently related to sadness and depression. Finally, neutral and disgusting new words elicited more activations in the fusiform gyrus, the lingual gyrus, and the lateral occipital cortex than sad new words.

The overall high accuracy in the evaluation phase of the training session indicated successful acquisition of emotional connotations beyond simply associating each pseudoword with each specific face, as participants were able to correctly apply the new words to new faces with the appropriate expressions (within-modality generalization) or even to sentences with emotional content (cross-modality generalization). There was no significant difference among the three emotions regarding accuracy in both tests although there was the tendency that participants performed better at generalizing disgusting new words to disgusting sentences. The categorial design of the pseudowords could contribute to the high accuracy since they served as proxies of real emotional words that are often organized as morphological sets with the same root (e.g., disgust, disgusting, disgusted)

In the current study, processing disgusting and neutral new words elicited larger EPN amplitudes than sad new words in the right posterior electrodes. Such a distribution was commonly found in studies using faces (Langeslag & van Strien, 2018; Mühlberger et al., 2009; Zhao et al., 2017) and pictures (Junghofer et al., 2001; Schupp, Stockburger, et al., 2006) as stimuli, which once again proved successful acquisition of emotional connotations for the new words. The larger EPN elicited by disgust compared with sadness may indicate that more attentional resources were allocated to processing disgusting than sad connotations, according to the literature on this ERP component (Schupp, Flaisch, et al., 2006; Schupp, Junghöfer, Öhman, et al., 2004; Schupp, Junghöfer, Weike, et al., 2004). Here, the emotional connotations were acquired with faces, and previous empirical evidence consistently showed that disgust expressions were easier to identify than sad expressions (Suzuki & Akiyama, 2013) and elicited larger occipital negativity around 250 ms than sadness expressions (Leleu et al., 2015). The enhanced EPN amplitudes for disgusting faces were in line with the results yielded in these studies. Moreover, previous studies also reported that the detection of sad facial expressions was slower than threatening faces (Öhman et al., 2001) and regarding ERP signatures, sad facial expressions elicited reduced negativity peaking at around 230 ms in the posterior area compared to fearful, angry, and surprising expressions (Balconi & Pozzoli, 2003). Such results were interpreted as reflecting differences in arousal between emotional stimuli. However, in the present study, there was no significant difference between the arousal of disgusting faces and sad faces yet disgust still demonstrating an attentional advantage. We can conclude that our empirical distinction between the acquired connotations of disgust and sadness relies more on emotional attributes rather than arousal and adds to the literature of the uniqueness of ERP patterns for disgust (Liu et al., 2015; Zhang et al., 2017).

Interestingly, neutral new words elicited larger EPN amplitudes than sad new words while no difference was found between neutral and disgusting new words. Such patterns were inconsistent with previous studies in which emotional stimuli usually elicited larger EPN than neutral stimuli (Aldunate et al., 2018; Junghofer et al., 2001; Schupp et al., 2003). However, previous studies have also demonstrated that EPN is sensitive to stimuli complexity since simple figure-ground scenes elicit larger amplitudes than naturalistic scenes (Bradley et al., 2007; Löw et al., 2013; Nordström & Wiens, 2012). In the present experiment, compared with the two categories of emotional faces, neutral faces were with less facial muscle movements and thus presented less distinguishable features that may facilitate processing. Similar to figure-ground scenes in previous studies, the enhanced EPN reflected difficulties in decoding neutral new words whose connotations were acquired with emotionally featureless neutral faces.

Such decoding difficulties extended to the late time window, reflected through the LPC component. There was extensive evidence that the LPC component was sensitive to the emotional content of the stimuli (Herbert et al., 2006, 2008; Kissler et al., 2009; Naumann et al., 1992). However, here the LPC amplitudes were enhanced for neutral new words compared with disgusting new words. Such a reversed pattern has also been reported in previous studies employing word identification (Hinojosa et al., 2009) and lexical-semantic decision tasks (Citron et al., 2011), in which neutral stimuli elicited larger LPC than emotional stimuli. It could be attributed to the less salient nature of neutral stimuli so that they required more sustained attention and evaluation to process (Citron, 2012). Therefore, the reduced LPC elicited by disgusting new words suggested that less attentional and evaluative efforts for disgust in the late time window.

This could be ascribed to the relatively short learning process in the current design that although participants were able to generalize the new words to describing disgusting connotations in new stimuli, no substantial semantic connotations were established. Therefore, compared to the robust neural activities in the early time window, the processing of disgusting new words was relatively automatic and subliminal in the late time window as LPC is the indicator of sustained attention and evaluation.

In addition to the ERP results, the source localization provided further evidence for demonstrating the brain dynamics of processing the three categories of learned pseudowords. Notably, disgusting new words elicited more activation than sad new words in a cluster comprising the insular cortex, the supramarginal gyrus the superior temporal gyrus. Such a result further proved that the insula is a main neural region in the disgust processing network (Calder et al., 2000; Krolak-Salmon et al., 2003; Wright et al., 2004). Meanwhile, the lateralized distribution of the activation in the right hemisphere was also in line with previous studies on disgusting facial expressions (Phillips et al., 1997; Sambataro et al., 2006), which once again indicates that the connotations of the new words were successfully acquired through the disgusting faces. In addition, the more activations in part of the supramarginal gyrus, which was reported to be involved in having empathy with other people(Hoffmann et al., 2016; Silani et al., 2013), and the superior temporal gyrus, which involves in emotional facial expression perception (Bigler et al., 2007; Phillips et al., 1998), also demonstrated the attention-capture nature of disgust compared with sadness in the early time window. On the other hand, sad new words elicited more activations in medial orbitofrontal and rostral anterior cingulate cortices than disgusting new words. According to the literature, both structures are engaged in sadness processing (Haas et al., 2008; Markowitsch et al., 2003; Zubieta et al., 2003) and the rostral anterior cingulate cortex is closely related to depression as well (Boes et al., 2008, 2018). Although the EPN amplitudes elicited by sad new words were less robust, such activations in these sadness processing-related structures indicated that the acquired sad connotations modulate written word processing in the early time window. Finally, an occipital cluster consisting of the lingual gyrus, the fusiform gyrus and the lateral occipital cortex was identified. The activation pattern here was identical to the interaction manifested in the ERP results. These three structures were reported to be associated with face processing both in healthy participants (Eger et al., 2004; Kim et al., 2007; Rossion et al., 2003) and in participants with brain lesions (Allison et al., 1994; Dinkelacker et al., 2011; Wada & Yamamoto, 2001). The enhanced activations further demonstrated the more attention captured for the alerting nature of disgust and decoding difficulty of neutrality of the two categories of new words.

The ERP and source localization results of the present experiment suggested that the acquired emotional connotations effectively affected the processing of previously meaningless pseudowords. Previous studies on second language embodiment have proposed that bilinguals simulate actions and emotions expressed by words in their second language when processing them (Baumeister et al., 2017; Dudschig et al., 2014; Macedonia, 2015; Pasfield-Neofitou et al., 2015; Sheikh & Titone, 2016). The learning procedure and pseudowords in the current study have partially simulated the learning process of a new language and the results were in line with the conclusion of second language embodiment. Moreover, the current study extended the results of previous studies examining how emotional connotations influencing words processing using general positive and negative pictures (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015) by employing more specified negative emotions and more socially-engaged faces.

Conclusion

The current study demonstrates how acquired emotional connotations affect written word processing by pairing meaningless pseudowords with faces expressing disgust, sadness, and neutrality in a learning session and measuring the brain activities of processing these learned pseudowords in an implicit Go/NoGo lexical-semantic decision task. The learning session was effective for participants to acquire emotional connotations for the pseudowords, reflecting in the high accuracy in the generalization tests. The ERPs showed that the emotional connotations affect words processing in an early time window 206 – 242 ms and a late time window 400 – 500 ms. In the early time window, disgusting and neutral new words elicited larger EPN amplitudes than sad new words, indicating higher attentional resource allocation on processing the former than the latter. In the late time window, neutral new words elicited larger LPC amplitudes than disgusting new words, suggesting sustained decoding difficulties in processing less salient neutral connotations. Furthermore, the ERP modulations in the early time window were associated with source localization results. More activations were manifested in the right insula for disgusting new words than sad new words, which is in line with existing evidence of the insula being the neural locus of disgust processing. Sad new words, on the other hand, elicited more activations than disgusting new words in the rostral anterior cingulate, which is reported to be involved in sadness processing and depression. In addition, the higher attentional requirements for processing disgusting and neutral new words were reflected by the enhanced activations in the right occipital lobe. Taken together, the results of the current study extend previous evidence on acquired emotional connotations affecting written word processing by demonstrating the brain spatiotemporal dynamics of processing new words whose emotional connotations were acquired from their association with disgusting, sad, and neutral facial expressions.

General Discussion

The emotional dimension of word meaning is a topic of growing interest in neurolinguistics. This thesis focused on disgust-related meaning, since the emotion of disgust is a basic human emotion involving well-known brain mechanisms, although it has been relatively neglected by neurolinguistic researchers. In this sense, the thesis offers some novel objectives. Specifically, to demonstrate the neural dynamics of disgust-related words in a non-Indo-European language, to examine the acquisition of disgust-related connotations for new words in the context of facial expressions and emotional sentences, to explore the neural dynamics of new words acquired emotional connotations and, finally, to verify a neural embodiment hypothesis of disgust-related words, that is, whether the insula – a main neural network involved in disgust – is activated by these words / new words.

The first experiment examined whether disgust processing in Mandarin is different from that in alphabetic languages and whether the processing is embodied. The ERP results indeed suggested a different processing pattern than previous studies carried out in alphabetic languages (Ponz et al., 2014). Instead of EPN, enlarged P2 was found for disgust-related words, compared to neutral words, indicating higher allocation of attentional resources. This P2 effect could be related to phonological and orthographic integration of Mandarin. However, linguistic variables of the stimuli such as word frequency and number of strokes were strictly controlled, which excluded the possibility that the P2 component was due to linguistic factors. In addition, the pattern of larger P2 for disgust-related words than neutral words was similar to the EPN pattern previously reported in French, which further proved that here enlarged P2 indicates participants allocating more attentional resources on processing disgust-related words. Regarding the N400 component, rather than finding an enhanced N400 for disgust-related words as reported in the previous study, the present experiment yielded a reversed pattern. In the previous study with an alphabetic language (Ponz et al. 2014), the researchers ascribed the enhanced N400 for disgust-related words to the nature of the task, arguing that instructing participants to respond to irrelevant fillers (vehicle names) leads them to ignore disgust-related words. In this case, the N400 might be an indicator of semantic inhibition rather than integration. However, in the current experiment, the reversed N400 pattern was obtained using a similar task, in accordance with previous evidence suggesting N400 was usually reduced for emotional words reflecting a facilitation of semantic processing (Kanske & Kotz, 2007). Therefore, we conclude that the EPN and P2 components reflect brain mechanisms oriented to detect and allocate resources to emotional words, whereas the N400 modulation reveals further facilitation of semantic processing.

The first experiment also verified the neural embodiment of disgust in Mandarin by conducting source localization of the ERP signals. Most importantly, the results suggested that the anterior insula was more activated for disgust-related words than neutral words in the time window where the P2 component was discovered. This is consistent with previous neuroimaging studies that reported the activation of the insula for processing disgust stimuli of various modalities (Phillips et al., 1997; Schienle et al., 2017; Wicker et al., 2003; Wright et al., 2004)

After examining disgust processing in existing Mandarin words, the thesis turned to investigate the acquisition of disgusting connotations for new words. A learning paradigm with two associative contexts, faces, and sentences, was designed in the second experiment. Although, the focus of this experiment was the emotion of disgust, there were two contrasting conditions in the learning paradigm: neutral new words and sad new words. Neutral new words served as baseline, non-emotional condition, while sad new words provided a negative-valence contrast to examine the specificity of disgust-related meaning. The experimental hypothesis that faces are more effective for acquiring disgusting connotations of words than sentences was verified. Moreover, the results also provided additional evidence regarding the acquisition of sad and neutral connotations for new words. Sentences were slightly more efficient than faces for acquiring sad connotations, although such an advantage was only manifested in one of the two tests probing participants' emotion acquisition. The sentences used in the experiment were composed in the second-person perspective (e.g. Your dog is dead). Previous empirical evidence suggested that the pronoun ¨you¨, or the second-person perspective in general, makes readers more likely to feel the emotional valence and the affective states expressed by the material than the first-person perspective (Brunyé et al., 2011). Therefore, the sentences describing detailed sadness-inducing scenarios in a second-person perspective were more effective in triggering sad resonances in participants, which is in line with the endogenous nature of the emotion (Lench et al., 2016). Other than that, faces were advantageous in all other tests of the three emotions involved, which indicated that as the first channel available for humans to perceive emotions (Denham, 1998; Izard, 1971), faces still have a great impact on the acquisition of words' emotional meaning, even in adults. Such results also suggest that in second language learning, pairing emotional words with the corresponding facial expressions can play an important role in learning emotional meanings.

Based on the evidence that faces are more efficient than sentences in inducing the acquisition of emotional connotations for new words, the third experiment examined the brain dynamics of processing new words whose emotional connotations were acquired with faces. It was expected that these new words would elicit similar ERP patterns and activate the same brain structures as existing words carrying identical emotional connotations. Concerning the ERP patterns, some interesting findings were obtained. Firstly, differential effects associated with new word emotional connotation were observed for the EPN component. However, contrary to the commonly found effect that the EPN is enhanced by emotional words compared with neutral words, in the current experiment, both disgusting and neutral new words elicited larger EPN than sad new words. The anomalous modulation of EPN by neutral new words was unexpected. As a component indexing attentional allocation, EPN is sensitive to stimuli with more salient characteristics such as emotional words (Junghofer et al., 2001; Schupp, Junghöfer, Öhman, et al., 2004; Schupp, Junghöfer, Weike, et al., 2004). In the current experimental design, in addition to the three categories of learned new words, a set of unlearned new words and a set of real neutral words were included as control baselines for testing learning and lexicalization effects. Compared with them, the connotations of the learned neutral new words were acquired through intensive training just prior to the ERP recording session, which made these learned new words more relevant and salient in the experiment and thus elicited larger EPN. There have been arguments proposing that the emotional EPN effect is task-independent and is not affected by processing depth, emotional nature of the task, or self-referentiality (Citron, 2012). However, the results of the current experiment suggested that in a learning paradigm, the emotional effect of EPN can be overwhelmed by the learning procedure and coexisting neutral stimuli. The neutral faces in the learning session were less distinguishable due to their relatively fewer muscle movements compared to emotional ones and thus increased decoding difficulties of the neutral new words. Such results were consistent with previous studies reporting the EPN as a component sensitive to stimuli complexity (Bradley et al., 2007; Löw et al., 2013; Nordström & Wiens, 2012).

In the late time window, compared with the first experiment in this thesis performed with existent Mandarin words, the N400 effect was missing and the LPC pattern was reversed between disgusting and neutral new words. These late components are indicators of semantic integration (Kutas & Federmeier, 2000) and prolonged evaluation (Citron, 2012). The absence of the N400 effect suggested that although the new words have acquired emotional connotations through the rapid learning procedure using faces, they did not necessarily acquire semantic meanings. In real life, children first acquire emotional concepts through facial expressions of their caregivers but learn linguistic labels for various emotions and words containing emotional connotations gradually, over an extended period of time, as their language proficiency improves (Markham & Adams, 1992; Vicari et al., 2000). Therefore, the learning with faces in the third experiment simulated only the initial stage of emotional connotation acquisition for new words, without reaching a consolidate representation in semantic memory. Regarding the LPC pattern, previous studies have reported that it is modulated only when the emotional content of the stimuli is relevant to the task or when a deep semantic processing is required but not by shallow processing as in lexical decision or orthographic judgment tasks (Fischler & Bradley, 2006). In the current experiment, the background task was to only respond to vehicle names included as fillers. In this case, the semantic processing of emotional and neutral new words was incidental and shallow, since no explicit emotional judgment was requested for them. For this reason, the LPC amplitude was not modulated by emotional new words, rather LPC increased for neutral new words, which are less salient and distinguishable from the real word fillers that all possess neutral valence, whereas disgusting new words were easily processed because of their salient emotional connotations. Finally, the source estimation analysis for the early time window confirmed the neural embodiment hypothesis in the sense that the anterior insula was more active during the processing of disgusting new words, whereas more activation of the anterior cingulate cortex was associated with sad new words. These results are in accordance with previous empirical evidence yielded from disgust (Phillips et al., 1997; Schienle et al., 2017; Wicker et al., 2003; Wright et al., 2004) and sadness (Niida & Mimura, 2017; Ramirez-Mahaluf et al., 2018; Webb et al., 2018) processing.

A plausible neural model to explain associative learning in our second and third experiments is as follows. The facial expressions of disgust triggered activations in the participants' emotional machinery through mirror neurons mechanisms, which in the case of disgust expression includes the insula. Concerning the processing of facial expressions, previous studies have shown that emotions can be activated in oneself by observing other people's motor or vocal emotional expressions based on the mirror neuron system (Baumeister et al., 2017; Gallese et al., 2004; Niedenthal, 2007). Studies investigating the first-person experience of disgust and the recognition of disgust in other people have provided more refined and specific supportive evidence for the findings of the current study (Calder et al., 2000; Wicker et al., 2003). Secondly, the pronounceable pseudowords used in this study would be encoded by the grapheme-to-phoneme conversion mechanisms in the brain including the left IFG (pars triangularis) and the visual word form area (fusiform gyrus) (Taylor et al., 2013). Finally, the co-occurrence of pseudowords and facial expressions of disgust could determine a simultaneous activation of neural assemblies in the insula and in the visual word form and left IFG areas inducing a Hebbian learning mechanism (neurons that fire together for a while strengthen their mutual connections and thus become more tightly associated) (Hebb, 1949). In this case, a subsequent presentation of a learned new word could activate specific neurons of the visual word form area and left IFG that trigger activation in specific neurons related to the associated emotion; for instance, the insula in the case of disgusting new words. Such a Hebbian learning model has been proposed to explain that action-related new words, adquired by means of associative learning paradigms, activate neural motor processes (Fargier et al., 2012; Liuzzi et al., 2010; Pulvermüller, 2005). This study suggested that the Hebbian learning mechanisms could also underlie the learning of emotional connotations of words.

Conclusions

1. The processing of emotional words in Mandarin elicited ERP signatures for disgust-related meaning, about 200 ms after the word onset (EPN and P2 components), which indicates early attention to disgust-related words. Also, an attenuated N400-like component and an enhanced LPC-like component for disgust-related words, compared to neutral words, suggested a facilitation effect of lexico-semantic processes.

2. The processing of disgust-related words in Mandarin also confirmed the neural embodiment hypothesis, as the main neural source of the early time window effects (EPN and P2) was the anterior insula, which has been associated in the literature with the processing of disgust in various modalities of stimuli.

3. Using an associative learning paradigm, facial expressions have been found to be more effective than emotional sentences as associative contexts in inducing connotations of disgust in new words. This conclusion is based on the superior performance of the face-trained group on the within-modality generalization test (correctly attributing disgusting novel words to new faces) and on the cross-modality generalization test (correctly attributing disgusting novel words to emotional sentences).

4. After acquiring emotional connotations in an associative learning paradigm with facial expressions, disgusting novel words elicited larger amplitudes in the EPN component of the ERPs than sad novel words, again indicating early attention to disgust-related meaning acquired after a short associative training.

5. Neutral novel words produced paradoxical results in the ERPs. They do not differ from disgusting novel words in the early ERP's time window (EPN), but they elicited larger amplitudes in the LPC component in comparison to emotional novel

words of disgust and sadness. Given the fact that neutral facial expressions are relatively ambiguous, it is likely that this enhanced LPC for the associated neutral new words reflects sustained decoding difficulties in processing less salient neutral connotations.

6. Most importantly, the neural embodiment hypothesis was confirmed for novel words with acquired emotional connotations. That is, disgusting new words increased activation in the anterior insula compared to sad new words during the EPN time window. Moreover, sad new words induced more activation than disgusting new words in the anterior cingulate cortex, a region frequently associated with sadness and depression.

7. This thesis does not provide direct evidence on the neural mechanisms involved in learning words' emotional connotations in the context of faces. Nonetheless, a plausible explanation may depend on well-known mechanisms reported in the literature, such as the mirror neuron system that would encode facial expressions in the anterior insula, the Broca area to encode pronounceable pseudowords, and most importantly the Hebbian learning mechanism that strengthens the mutual connections between neural populations which are activated simultaneously in those regions to produce their association.

References

Acheson, D. J., & Hagoort, P. (2013). Stimulating the brain's language network: Syntactic ambiguity resolution after TMS to the inferior frontal gyrus and middle temporal gyrus. *Journal of Cognitive Neuroscience*, *25*(10), 1664–1677. https://doi.org/10.1162/jocn_a_00430

Adolphs, R., Russell, J. A., & Tranel, D. (1999). A role for the human amygdala in recognizing emotional arousal from unpleasant stimuli. *Psychological Science*, 10(2), 167–171. https://doi.org/10.1111/1467-9280.00126

Aldunate, N., López, V., & Bosman, C. A. (2018). Early Influence of Affective Context on Emotion Perception: EPN or Early-N400? *Frontiers in Neuroscience*, *12*(OCT), 708. https://doi.org/10.3389/fnins.2018.00708

Allison, T., Ginter, H., McCarthy, G., Nobre, A. C., Puce, A., Luby, M., & Spencer, D. D. (1994). Face recognition in human extrastriate cortex. *Journal of Neurophysiology*, *71*(2), 821–825. https://doi.org/10.1152/jn.1994.71.2.821

Angyal, A. (1941). Disgust and related aversions. *Journal of Abnormal and Social Psychology*, *36*(3), 393–412. https://doi.org/10.1037/h0058254

Aragão, R. (2011). Beliefs and emotions in foreign language learning. *System*, *39*(3), 302–313. https://doi.org/10.1016/j.system.2011.07.003

Baggott, S., Palermo, R., & Fox, A. M. (2011). Processing emotional category congruency between emotional facial expressions and emotional words. *Cognition and Emotion*, *25*(2), 369–379. https://doi.org/10.1080/02699931.2010.488945

Balconi, M., & Pozzoli, U. (2003). Face-selective processing and the effect of pleasant and unpleasant emotional expressions on ERP correlates. *International Journal* *of Psychophysiology*, *49*(1), 67–74. https://doi.org/10.1016/S0167-8760(03)00081-3

Barsalou, L. W. (2008). Grounded Cognition. *Annual Review of Psychology*, *59*(1), 617–645. https://doi.org/10.1146/annurev.psych.59.103006.093639

Baumeister, J. C., Foroni, F., Conrad, M., Rumiati, R. I., & Winkielman, P. (2017). Embodiment and emotional memory in first vs. second language. *Frontiers in Psychology*, *8*(MAR), 394. https://doi.org/10.3389/fpsyg.2017.00394

Bayer, M., Grass, A., & Schacht, A. (2019). Associated valence impacts early visual processing of letter strings: Evidence from ERPs in a cross-modal learning paradigm. *Cognitive, Affective and Behavioral Neuroscience*, *19*(1), 98–108. https://doi.org/10.3758/s13415-018-00647-2

Beall, P. M., & Herbert, A. M. (2008). The face wins: Stronger automatic processing of affect in facial expressions than words in a modified Stroop task. *Cognition and Emotion*, *22*(8), 1613–1642. https://doi.org/10.1080/02699930801940370

Bigler, E. D., Mortensen, S., Neeley, E. S., Ozonoff, S., Krasny, L., Johnson, M., Lu, J., Provencal, S. L., McMahon, W., & Lainhart, J. E. (2007). Superior temporal gyrus, language function, and autism. *Developmental Neuropsychology*, *31*(2), 217–238. https://doi.org/10.1080/87565640701190841

Blessing, A., Zöllig, J., Weierstall, R., Dammann, G., & Martin, M. (2013). Evaluative conditioning with facial stimuli in dementia patients. *Journal of Neurodegenrative Diseases*, *2013,* 854643. https://doi.org/10.1155/2013/854643

Bloom, L. (2000). The intentionality of word learning: How to learn a word, any word. In R. M. Golinkoff, K. Hirsh-Pasek, L. Bloom, L. B. Smith, A. L. Woodward, N. Akhtar, M. Tomasello & G. Hollich (Eds.), *Becoming a word learner: A debate on lexical acquisition* (pp. 19–50). New York: Oxford.

Bobrow, D. G., & Winograd, T. (1977). An Overview of KRL, a Knowledge Representation Language. *Cognitive Science*, *1*(1), 3–46. https://doi.org/10.1207/s15516709cog0101_2

Boes, A. D., McCormick, L. M., Coryell, W. H., & Nopoulos, P. (2008). Rostral Anterior Cingulate Cortex Volume Correlates with Depressed Mood in Normal Healthy Children. *Biological Psychiatry*, *63*(4), 391–397. https://doi.org/10.1016/j.biopsych.2007.07.018

Boes, A. D., Uitermarkt, B. D., Albazron, F. M., Lan, M. J., Liston, C., Pascual-Leone, A., Dubin, M. J., & Fox, M. D. (2018). Rostral anterior cingulate cortex is a structural correlate of repetitive TMS treatment response in depression. *Brain Stimulation*, *11*(3), 575–581. https://doi.org/10.1016/j.brs.2018.01.029

Bolby, J. (1980). *Attachment and loss: Vol 3. Loss: Sadness and depression*. London: Hogarth Press.

Bradley, M. M., Hamby, S., Löw, A., & Lang, P. J. (2007). Brain potentials in perception: Picture complexity and emotional arousal. *Psychophysiology*, *44*(3), 364–373. https://doi.org/10.1111/j.1469-8986.2007.00520.x

Brosch, T., Sander, D., Pourtois, G., & Scherer, K. R. (2008). Beyond fear: Rapid spatial orienting toward positive emotional stimuli. *Psychological Science*, *19*(4), 362–370. https://doi.org/10.1111%2Fj.1467-9280.2008.02094.x

Calder, A. J., Keane, J., Manes, F., Antoun, N., & Young, A. W. (2000). Impaired recognition and experience of disgust following brain injury. *Nature Neuroscience*, *3*(11), 1077–1078. https://doi.org/10.1038/80586

Cantone, M., Lanza, G., Bella, R., Pennisi, G., Santalucia, P., Bramanti, P., & Pennisi, M. (2019). Fear and disgust: Case report of two uncommon emotional disturbances evoked by visual disperceptions after a right temporal-insular stroke. *BMC Neurology*, *19*(1), 193. https://doi.org/10.1186/s12883-019-1417-0

Carretié, L., Hinojosa, J. A., Albert, J., López-Martín, S., de La Gándara, B. S., Igoa, J. M., & Sotillo, M. (2008). Modulation of ongoing cognitive processes by emotionally intense words. *Psychophysiology*, *45*(2), 188–196. https://doi.org/10.1111/j.1469-8986.2007.00617.x

Carretié, L., Mercado, F., Tapia, M., & Hinojosa, J. A. (2001). Emotion, attention, and the "negativity bias", studied through event-related potentials. *International Journal of Psychophysiology*, *41*(1), 75–85. https://doi.org/10.1016/S0167-8760(00)00195-1

Carver, C. S. (2004). Negative affects deriving from the behavioral approach system. *Emotion*, *4*(1), 3–22. https://doi.org/10.1037/1528-3542.4.1.3

Case, L. K., Laubacher, C. M., Olausson, H., Wang, B., Spagnolo, P. A., & Bushnell, M. C. (2016). Encoding of touch intensity but not pleasantness in human primary somatosensory cortex. *Journal of Neuroscience*, *36*(21), 5850–5860. https://doi.org/10.1523/JNEUROSCI.1130-15.2016

Cavanna, A. E., & Trimble, M. R. (2006). The precuneus: A review of its functional anatomy and behavioural correlates. In *Brain* (Vol. 129, Issue 3, pp. 564–583). Oxford University Press. https://doi.org/10.1093/brain/awl004

Chaffin, R., Morris, R. K., & Seely, R. E. (2001). Learning new word meanings from context: A study of eye movements. *Journal of Experimental Psychology: Learning Memory and Cognition*, *27*(1), 225–235. https://doi.org/10.1037/0278-7393.27.1.225

Charniak, E. (1978). On the use of framed knowledge in language comprehension. *Artificial Intelligence*, *11*(3), 225–265. https://doi.org/10.1016/0004-3702(78)90002-4

Chen, B., Liu, W., Wang, L., Peng, D., & Perfetti, C. A. (2007). The timing of graphic, phonological and semantic activation of high and low frequency Chinese characters: an ERP study. *Progress in Natural Science*, *17*, 62–70.

Chwilla, D. J., Virgillito, D., & Vissers, C. T. W. M. (2011). The relationship of language and emotion: N400 support for an embodied view of language comprehension. *Journal of Cognitive Neuroscience*, *23*(9), 2400–2414. https://doi.org/10.1162/jocn.2010.21578

Citron, F. M. M., Weekes, B. S., & Ferstl, E. C. (2011). Neural correlates of emotion word processing: The interaction between emotional valence and arousal. *Psychophysiology*, *48*, S3–S3.

Citron, F. M.M. (2012). Neural correlates of written emotion word processing: A review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language*, *122*(3), 211–226. https://doi.org/10.1016/j.bandl.2011.12.007

Curtis, Val, Aunger, R., & Rabie, T. (2004). Evidence that disgust evolved to protect from risk of disease. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *271*(suppl_4). https://doi.org/10.1098/rsbl.2003.0144

Curtis, Valerie, & Biran, A. (2001). Dirt, disgust, and disease: Is hygiene in our genes? In *Perspectives in Biology and Medicine* (Vol. 44, Issue 1, pp. 17–31). Johns Hopkins University Press. https://doi.org/10.1353/pbm.2001.0001

Darwin, C. (1872). *The expression of the emotions in man and animals*. London: John Murray.

Davey, G. C. L. (1993). Factors Influencing Self-rated Fear to a Novel Animal. *Cognition and Emotion*, *7*(5), 461–471. https://doi.org/10.1080/02699939308409199

de Houwer, J., Baeyens, F., & Eelen, P. (1994). Verbal evaluative conditioning with undetected US presentations. *Behaviour Research and Therapy*, *32*(6), 629–633. https://doi.org/10.1016/0005-7967(94)90017-5

de Houwer, J., Hendrickx, H., & Baeyens, F. (1997). Evaluative learning with "subliminally" presented stimuli. *Consciousness and Cognition*, *6*(1), 87–107. https://doi.org/10.1006/ccog.1996.0281

de Vega, M. de, Glenberg, A., & Graesser, A. (2008). *Symbols and embodiment: Debates on meaning and cognition*. Oxford University Press.

Denham, S. A. (1998). *Emotional development in young children*. New York: Guilford Press.

Devlin, J. T., Jamison, H. L., Gonnerman, L. M., & Matthews, P. M. (2006). The role of the posterior fusiform gyrus in reading. *Journal of Cognitive Neuroscience*, *18*(6), 911–922. https://doi.org/10.1162/jocn.2006.18.6.911

Ding, J., Wang, L., & Yang, Y. (2016). The dynamic influence of emotional words on sentence comprehension: An ERP study. *Cognitive, Affective and Behavioral Neuroscience*, *16*(3), 433–446. https://doi.org/10.3758/s13415-016-0403-x

Dinkelacker, V., Grüter, M., Klaver, P., Grüter, T., Specht, K., Weis, S., Kennerknecht, I., Elger, C. E., & Fernandez, G. (2011). Congenital prosopagnosia: Multistage anatomical and functional deficits in face processing circuitry. *Journal of Neurology*, *258*(5), 770–782. https://doi.org/10.1007/s00415-010-5828-5

Dreyer, F. R., Frey, D., Arana, S., Saldern, S. von, Picht, T., Vajkoczy, P., & Pulvermüller, F. (2015). Is the motor system necessary for processing action and abstract emotion words? Evidence from focal brain lesions. *Frontiers in Psychology*, *6*(NOV), 1661. https://doi.org/10.3389/fpsyg.2015.01661

Dudschig, C., de la Vega, I., & Kaup, B. (2014). Embodiment and second-language: Automatic activation of motor responses during processing spatially associated L2 words and emotion L2 words in a vertical Stroop paradigm. *Brain and Language*, *132*, 14–21. https://doi.org/10.1016/j.bandl.2014.02.002

Eden, A. S., Zwitserlood, P., Keuper, K., Junghöfer, M., Laeger, I., Zwanzger, P., & Dobel, C. (2014). All in its proper time: Monitoring the emergence of a memory bias for novel, arousing-negative words in individuals with high and low trait anxiety. *PLoS ONE*, *9*(6). https://doi.org/10.1371/journal.pone.0098339

Eger, E., Schyns, P. G., & Kleinschmidt, A. (2004). Scale invariant adaptation in fusiform face-responsive regions. *NeuroImage*, *22*(1), 232–242. https://doi.org/10.1016/j.neuroimage.2003.12.028

Ekman, P, Hager, J. C., & Friesen, W. V. (2002). *Facial action coding system: The manual*. Salt Lake City: Research Nexus.

Ekman, P. (1992a). An argument for basic emotions. *Cognition and Emotion*, *6*(3–4), 169–200. https://doi.org/10.1080/02699939208411068

Ekman, P. (1992b). Facial expressions of emotion: New findings, new questions. *Psychological Science*, *3*(1), 34–38. https://doi.org/10.1111%2Fj.1467-9280.1992.tb00253.x

Ekman, P. (1993). Facial expression and emotion. *American Psychologist*, *48*(4), 384–392. https://doi.org/10.1037/0003-066X.48.4.384

Fan, L., Xu, Q., Wang, X., Xu, F., Yang, Y., & Lu, Z. (2018). The automatic activation of emotion words measured using the emotional face-word Stroop task in late

Chinese–English bilinguals. *Cognition and Emotion*, *32*(2), 315–324. https://doi.org/10.1080/02699931.2017.1303451

Fan, L., Xu, Q., Wang, X., Xu, F., Yang, Y., & Lu, Z. (2018). The automatic activation of emotion words measured using the emotional face-word Stroop task in late Chinese–English bilinguals. *Cognition and Emotion*, *32*(2), 315–324. https://doi.org/10.1080/02699931.2017.1303451

Fan, L., Xu, Q., Wang, X., Zhang, F., Yang, Y., & Liu, X. (2016). Neural Correlates of Task-Irrelevant First and Second Language Emotion Words – Evidence from the Emotional Face–Word Stroop Task. *Frontiers in Psychology*, *7*(NOV), 1672. https://doi.org/10.3389/fpsyg.2016.01672

Fargier, R., Paulignan, Y., Boulenger, V., Monaghan, P., Reboul, A., & Nazir, T. A. (2012). Learning to associate novel words with motor actions: Language-induced motor activity following short training. *Cortex*, *48*(7), 888–899. https://doi.org/10.1016/j.cortex.2011.07.003

Fernández-Dols, J.-M., & Crivelli, C. (2013). Emotion and expression: Naturalistic studies. *Emotion Review*, *5*(1), 24–29. https://doi.org/10.1177%2F1754073912457229

Ferrer, R. A., Grenen, E. G., & Taber, J. M. (2015). Effectiveness of Internet-based affect induction procedures: A systematic review and meta-analysis. *Emotion*, *15*(6), 752–762. https://doi.org/10.1037/emo0000035

Fields, E. C., & Kuperberg, G. R. (2012). It's all about you: An ERP study of emotion and self-relevance in discourse. *NeuroImage*, *62*(1), 562–574. https://doi.org/10.1016/j.neuroimage.2012.05.003

Fischler, I., & Bradley, M. (2006). Event-related potential studies of language and emotion: words, phrases, and task effects. In *Progress in Brain Research* (Vol. 156, pp. 185–203). Elsevier. https://doi.org/10.1016/S0079-6123(06)56009-1

Foroni, F. (2015). Do we embody second language? Evidence for “partial” simulation during processing of a second language. *Brain and Cognition*, *99*, 8–16. https://doi.org/10.1016/j.bandc.2015.06.006

Foroni, F., & Semin, G. R. (2009). Language that puts you in touch with your bodily feelings: The multimodal responsiveness of affective expressions. *Psychological Science*, *20*(8), 974–980. https://doi.org/10.1111/j.1467-9280.2009.02400.x

Franken, I. H. A., Gootjes, L., & van Strien, J. W. (2009). Automatic processing of emotional words during an emotional Stroop task. *NeuroReport*, *20*(8), 776–781. https://doi.org/10.1097/WNR.0b013e32832b02fe

Frazier, T. W., Strauss, M. E., & Steinhauer, S. R. (2004). Respiratory sinus arrhythmia as an index of emotional response in young adults. *Psychophysiology*, *41*(1), 75–83. https://doi.org/10.1046/j.1469-8986.2003.00131.x

Frishkoff, G. A., Perfetti, C. A., & Collins-Thompson, K. (2010). Lexical quality in the brain: ERP evidence for robust word learning from context. *Developmental Neuropsychology*, *35*(4), 376–403. https://doi.org/10.1080/87565641.2010.480915

Fritsch, N., & Kuchinke, L. (2013). Acquired affective associations induce emotion effects in word recognition: An ERP study. *Brain and Language*, *124*(1), 75–83. https://doi.org/10.1016/j.bandl.2012.12.001

Gallese, V. (2008). Mirror neurons and the social nature of language: The neural exploitation hypothesis. *Social Neuroscience*, *3*(3–4), 317–333. https://doi.org/10.1080/17470910701563608

Gallese, V., Keysers, C., & Rizzolatti, G. (2004). A unifying view of the basis of social cognition. *Trends in Cognitive Sciences*, *8*(9), 396–403. https://doi.org/10.1016/j.tics.2004.07.002

Gantiva, C., Araujo, A., Calderón, L., Gómez, P., & Reina, F. (2019). Psychophysiological responses to facial expression of surprise, sadness, and disgust. *Australian Journal of Psychology*, *71*(2), 100–107. https://doi.org/10.1111/ajpy.12222

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin and Review*, *9*(3), 558–565. https://doi.org/10.3758/BF03196313

Gootjes, L., Coppens, L. C., Zwaan, R. A., Franken, I. H. A., & van Strien, J. W. (2011). Effects of recent word exposure on emotion-word Stroop interference: An ERP study. *International Journal of Psychophysiology*, *79*(3), 356–363. https://doi.org/10.1016/j.ijpsycho.2010.12.003

Gramfort, A., Papadopoulo, T., Olivi, E., & Clerc, M. (2010). OpenMEEG: Opensource software for quasistatic bioelectromagnetics. *BioMedical Engineering Online*, *9*(1), 45. https://doi.org/10.1186/1475-925X-9-45

Griffiths, T. L., & Steyvers, M. (2004). Finding scientific topics. *Proceedings of the National Academy of Sciences of the United States of America*, *101*(SUPPL. 1), 5228–5235. https://doi.org/10.1073/pnas.0307752101

Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: The acute effects of inhibiting negative and positive emotion. *Journal of Abnormal Psychology*, *106*(1), 95–103. https://doi.org/10.1037/0021-843X.106.1.95

Gu, B., Liu, B., Wang, H., Beltrán, D., de Vega, M. (2021). Learning new words´ emotional meanings in the contexts of faces and sentences. *Psicológica*, in press.

Haas, B. W., Constable, R. T., & Canli, T. (2008). Stop the sadness: Neuroticism is associated with sustained medial prefrontal cortex response to emotional facial expressions. *NeuroImage*, *42*(1), 385–392. https://doi.org/10.1016/j.neuroimage.2008.04.027

Hadland, K. A., Rushworth, M. F. S., Gaffan, D., & Passingham, R. E. (2003). The effect of cingulate lesions on social behaviour and emotion. *Neuropsychologia*, *41*(8), 919–931. https://doi.org/10.1016/S0028-3932(02)00325-1

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic Representation of Action Words in Human Motor and Premotor Cortex. *Neuron*, *41*(2), 301–307. https://doi.org/10.1016/S0896-6273(03)00838-9

Havas, D. A., Glenberg, A. M., & Rinck, M. (2007). Emotion simulation during language comprehension. *Psychonomic Bulletin and Review*, *14*(3), 436–441. https://doi.org/10.3758/BF03194085

Havas, D. A., Glenberg, A. M., Gutowski, K. A., Lucarelli, M. J., & Davidson, R. J. (2010). Cosmetic use of botulinum toxin-a affects processing of emotional language. *Psychological Science*, *21*(7), 895–900. https://doi.org/10.1177/0956797610374742

Hebb, D. O. (1949). *The organization of behavior; a neuropsychological theory*. New York: Wiley.

Herbert, C., Junghofer, M., & Kissler, J. (2008). Event related potentials to emotional adjectives during reading. *Psychophysiology*, *45*(3), 487–498. https://doi.org/10.1111/j.1469-8986.2007.00638.x

Herbert, C., Kissler, J., Junghofer, M., Peyk, P., & Rockstroh, B. (2006). Processing of emotional adjectives: Evidence from startle EMG and ERPs. *Psychophysiology*, *43*(2), 197–206. https://doi.org/10.1111/j.1469-8986.2006.00385.x

Herbert, C., Pauli, P., & Herbert, B. M. (2011). Self-reference modulates the processing of emotional stimuli in the absence of explicit self-referential appraisal instructions. *Social Cognitive and Affective Neuroscience*, *6*(5), 653–661.

Herbert, Cornelia, Herbert, B. M., Ethofer, T., & Pauli, P. (2011). His or mine? The time course of self-other discrimination in emotion processing. *Social Neuroscience*, *6*(3), 277–288. https://doi.org/10.1080/17470919.2010.523543

Herbert, Cornelia, Junghofer, M., & Kissler, J. (2008). Event related potentials to emotional adjectives during reading. *Psychophysiology*, *45*(3), 487–498. https://doi.org/10.1111/j.1469-8986.2007.00638.x

Herbert, Cornelia, Kissler, J., Junghofer, M., Peyk, P., & Rockstroh, B. (2006). Processing of emotional adjectives: Evidence from startle EMG and ERPs. *Psychophysiology*, *43*(2), 197–206. https://doi.org/10.1111/j.1469-8986.2006.00385.x

Hinojosa, J. A., Carretié, L., Valcárcel, M. A., Méndez-Bértolo, C., & Pozo, M. A. (2009). Electrophysiological differences in the processing of affective information in words and pictures. *Cognitive, Affective and Behavioral Neuroscience*, *9*(2), 173–189. https://doi.org/10.3758/CABN.9.2.173

Hinojosa, J. A., Méndez-Bértolo, C., & Pozo, M. A. (2010). Looking at emotional words is not the same as reading emotional words: Behavioral and neural correlates. *Psychophysiology*, *47*(4), 748–757. https://doi.org/10.1111/j.1469-8986.2010.00982.x

Hoffmann, F., Koehne, S., Steinbeis, N., Dziobek, I., & Singer, T. (2016). Preserved Self-other Distinction During Empathy in Autism is Linked to Network Integrity of Right Supramarginal Gyrus. *Journal of Autism and Developmental Disorders*, *46*(2), 637–648. https://doi.org/10.1007/s10803-015-2609-0

Hofmann, M. J., Kuchinke, L., Tamm, S., Võ, M. L. H., & Jacobs, A. M. (2009). Affective processing within 1/10th of a second: High arousal is necessary for early facilitative processing of negative but not positive words. *Cognitive, Affective and Behavioral Neuroscience*, *9*(4), 389–397. https://doi.org/10.3758/9.4.389

Hofmann, M. J., Kuchinke, L., Tamm, S., Võ, M. L. H., & Jacobs, A. M. (2009). Affective processing within 1/10th of a second: High arousal is necessary for early facilitative processing of negative but not positive words. *Cognitive, Affective and Behavioral Neuroscience*, *9*(4), 389–397. https://doi.org/10.3758/9.4.389

Horchak, O. v., Giger, J. C., Cabral, M., & Pochwatko, G. (2014). From demonstration to theory in embodied language comprehension: A review. *Cognitive Systems Research*, *29–30*(1), 66–85. https://doi.org/10.1016/j.cogsys.2013.09.002

Huang, H., Luo, Y., Feng, T., & Li, H. (2010). The neural basis of disgust processing. *Advances in Psychological Science*, *18*(9).

Izard, C. E. (1971). *The face of emotion*. New York: Appleton-Century-Crofts.

Izard, C. E., & Buechler, S. (1980). Aspects of consciousness and personality in terms of differential emotions theory. In R. Plutchik & H. Kellerman (Eds.), *Emotion: Theory, research, and experience: Vol. I* (Vol. I, pp. 165–188). Academic Press.

Jabbi, M., Bastiaansen, J., & Keysers, C. (2008). A common anterior insula representation of disgust observation, experience and imagination shows divergent functional connectivity pathways. *PLoS ONE*, *3*(8). https://doi.org/10.1371/journal.pone.0002939

Jones, C. L., Ward, J., & Critchley, H. D. (2010). The neuropsychological impact of insular cortex lesions. In *Journal of Neurology, Neurosurgery and Psychiatry*

(Vol. 81, Issue 6, pp. 611–618). BMJ Publishing Group. https://doi.org/10.1136/jnnp.2009.193672

Junghofer, M., Bradley, M. M., Elbert, T. R., & Lang, P. J. (2001). Fleeting images: A new look at early emotion discrimination. *Psychophysiology*, *38*(2), 175–178. https://doi.org/10.1111/1469-8986.3820175

Junghöfer, M., Rehbein, M. A., Maitzen, J., Schindler, S., & Kissler, J. (2017). An evil face? Verbal evaluative multi-CS conditioning enhances face-evoked mid-latency magnetoencephalographic responses. *Social Cognitive and Affective Neuroscience*, *12*(4), 695–705. https://doi.org/10.1093/scan/nsw179

Kanske, P., & Kotz, S. A. (2007). Concreteness in emotional words: ERP evidence from a hemifield study. *Brain Research*, *1148*(1), 138–148. https://doi.org/10.1016/j.brainres.2007.02.044

Kanske, P., & Kotz, S. A. (2011). Emotion triggers executive attention: Anterior cingulate cortex and amygdala responses to emotional words in a conflict task. *Human Brain Mapping*, *32*(2), 198–208. https://doi.org/10.1002/hbm.21012

Kar, B. R., Srinivasan, N., Nehabala, Y., & Nigam, R. (2018). Proactive and reactive control depends on emotional valence: a Stroop study with emotional expressions and words. *Cognition and Emotion*, *32*(2), 325–340. https://doi.org/10.1080/02699931.2017.1304897

Kar, B. R., Srinivasan, N., Nehabala, Y., & Nigam, R. (2018). Proactive and reactive control depends on emotional valence: a Stroop study with emotional expressions and words. *Cognition and Emotion*, *32*(2), 325–340. https://doi.org/10.1080/02699931.2017.1304897

Karolinska Directed Emotional Faces (KDEF) documents — Department of Experimental Clinical and Health Psychology — Ghent University. Retrieved

April 8, 2020, from https://www.ugent.be/pp/ekgp/en/research/research-groups/panlab/kdef

Kawashima, R., Roland, P. E., & O'Sullivan, B. T. (1995). Functional anatomy of reaching and visuomotor learning: a positron emission tomography study. *Cerebral Cortex*, *5*(2), 111–122. https://doi.org/10.1093/cercor/5.2.111

Keltner, D., & Kring, A. M. (1998). Emotion, social function, and psychopathology. *Review of General Psychology*, *2*(3), 320–342. https://doi.org/10.1037/1089-2680.2.3.320

Kim, S. E., Kim, J. W., Kim, J. J., Jeong, B. S., Choi, E. A., Jeong, Y. G., Kim, J. H., Ku, J., & Ki, S. W. (2007). The neural mechanism of imagining facial affective expression. *Brain Research*, *1145*(1), 128–137. https://doi.org/10.1016/j.brainres.2006.12.048

Kissler, J., Assadollahi, R., & Herbert, C. (2006). Emotional and semantic networks in visual word processing: insights from ERP studies. *Progress in Brain Research*, *156*, 147–183. https://doi.org/10.1016/S0079-6123(06)56008-X

Kissler, J., Herbert, C., Peyk, P., & Junghofer, M. (2007). Buzzwords: Early cortical responses to emotional words during reading. *Psychological Science*, *18*(6), 475–480. https://doi.org/10.1111/j.1467-9280.2007.01924.x

Kissler, J., Herbert, C., Winkler, I., & Junghofer, M. (2009). Emotion and attention in visual word processing-An ERP study. *Biological Psychology*, *80*(1), 75–83. https://doi.org/10.1016/j.biopsycho.2008.03.004

Kleinman, A., & Kleinman, J. (1985). Somatization: The interconnections in Chinese society among culture, depressive experiences, and the meanings of pain. In A. Kleinman & B. Good (Eds.), *Culture and depression: Studies in the* *anthropology and cross-cultural psychiatry of affect and disorder.* . University of California Press.

Kleinman, A., Anderson, J. M., Finkler, K., Frankenberg, R. J., & Young, A. (1986). Social Origins of Distress and Disease : Depression, Neurasthenia, and Pain in Modern China. *Current Anthropology*, *24*(5).

Kong, L., Zhang, B., Zhang, J. X., & Kang, C. (2012). P200 can be modulated by orthography alone in reading Chinese words. *Neuroscience Letters*, *529*(2), 161–165. https://doi.org/10.1016/j.neulet.2012.09.028

Kong, L., Zhang, J. X., Kang, C., Du, Y., Zhang, B., & Wang, S. (2010). P200 and phonological processing in Chinese word recognition. *Neuroscience Letters*, *473*(1), 37–41. https://doi.org/10.1016/j.neulet.2010.02.014

Kreibig, S. D., Wilhelm, F. H., Roth, W. T., & Gross, J. J. (2007). Cardiovascular, electrodermal, and respiratory response patterns to fear- and sadness-inducing films. *Psychophysiology*, *44*(5), 787–806. https://doi.org/10.1111/j.1469-8986.2007.00550.x

Krolak-Salmon, P., Hénaff, M. A., Isnard, J., Tallon-Baudry, C., Guénot, M., Vighetto, A., Bertrand, O., & Mauguière, F. (2003). An attention modulated response to disgust in human ventral anterior insula. *Annals of Neurology*, *53*(4), 446–453. https://doi.org/10.1002/ana.10502

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*(2), 149–174. https://doi.org/10.1006/jmla.1994.1008

Krumhansl, C. L. (1997). An exploratory study of musical emotions and psychophysiology. *Canadian Journal of Experimental Psychology*, *51*(4), 336–352. https://doi.org/10.1037/1196-1961.51.4.336

Kuchinke, L., Fritsch, N., & Müller, C. J. (2015). Evaluative conditioning of positive and negative valence affects P1 and N1 in verbal processing. *Brain Research*, *1624*, 405–413. https://doi.org/10.1016/j.brainres.2015.07.059

Kulke, L., Bayer, M., Grimm, A. M., & Schacht, A. (2019). Differential effects of learned associations with words and pseudowords on event-related brain potentials. *Neuropsychologia*, *124*, 182–191. https://doi.org/10.1016/j.neuropsychologia.2018.12.012

Kunzmann, U., & Grühn, D. (2005). Age differences in emotional reactivity: The sample case of sadness. *Psychology and Aging*, *20*(1), 47–59. https://doi.org/10.1037/0882-7974.20.1.47

Kutas, M., & Federmeier, K. D. (2000). Electrophysiology reveals semantic memory use in language comprehension. *Trends in Cognitive Sciences, 4*(12), 463–470). https://doi.org/10.1016/S1364-6613(00)01560-6

Landauer, T. K., & Dumais, S. T. (1997). A solution to Plato's problem: The latent semantic analysis theory of acquisition, induction, and representation of knowledge. *Psychological Review*, *104*(2), 211–240. https://doi.org/10.1037/0033-295X.104.2.211

Lane, R. D., Reiman, E. M., Ahern, G. L., Schwartz, G. E., & Davidson, R. J. (1997). Neuroanatomical correlates of happiness, sadness, and disgust. *American Journal of Psychiatry*, *154*(7), 926–933. https://doi.org/10.1176/ajp.154.7.926

Langeslag, S. J. E., & van Strien, J. W. (2018). Early visual processing of snakes and angry faces: An ERP study. *Brain Research*, *1678*, 297–303. https://doi.org/10.1016/j.brainres.2017.10.031

Lau, E. F., Phillips, C., & Poeppel, D. (2008). A cortical network for semantics: (De)constructing the N400. *Nature Reviews Neuroscience,* 9(12), 920–933. Nature Publishing Group. https://doi.org/10.1038/nrn2532

Lee, E., Kang, J. I., Park, I. H., Kim, J. J., & An, S. K. (2008). Is a neutral face really evaluated as being emotionally neutral? *Psychiatry Research*, *157*(1–3), 77–85. https://doi.org/10.1016/j.psychres.2007.02.005

Leleu, A., Godard, O., Dollion, N., Durand, K., Schaal, B., & Baudouin, J. Y. (2015). Contextual odors modulate the visual processing of emotional facial expressions: An ERP study. *Neuropsychologia*, *77*, 366–379. https://doi.org/10.1016/j.neuropsychologia.2015.09.014

Lench, H. C., Flores, S. A., & Bench, S. W. (2011). Discrete emotions predict changes in cognition, judgment, experience, behavior, and physiology: A meta-analysis of experimental emotion elicitations. *Psychological Bulletin*, *137*(5), 834–855. https://doi.org/10.1037/a0024244

Lench, H. C., Tibbett, T. P., & Bench, S. W. (2016). Exploring the toolkit of emotion: What do sadness and anger do for us? *Social and Personality Psychology Compass*, *10*(1), 11–25. https://doi.org/10.1111/spc3.12229

Levine, L. J., & Pizarro, D. A. (2004). Emotion and memory research: A grumpy overview. *Social Cognition,* *22*(5), 530–554. https://doi.org/10.1521/soco.22.5.530.50767

Lewis, P. A., Critchley, H., Rotshtein, P., & Dolan, R. J. (2007). Neural correlates of processing valence and arousal in affective words. *Cerebral Cortex*, *17*(3), 742–748. https://doi.org/10.1093/cercor/bhk024

Lindsay, S., & Gaskell, M. G. (2010). A complementary systems account of word learning in L1 and L2. Language Learning, 60, 45-63. https://doi.org/10.1111/j.1467-9922.2010.00600.x

Liu, Y., Zhang, D., & Luo, Y. (2015). How disgust facilitates avoidance: an ERP study on attention modulation by threats. *Social Cognitive & Affective Neuroscience.*, *10*(4), 598–604.

Liuzzi, G., Freundlieb, N., Ridder, V., Hoppe, J., Heise, K., Zimerman, M., Dobel, C., Enriquez-Geppert, S., Gerloff, C., Zwitserlood, P., & Hummel, F. C. (2010). The involvement of the left motor cortex in learning of a novel action word lexicon. *Current Biology*, *20*(19), 1745–1751. https://doi.org/10.1016/j.cub.2010.08.034

Löw, A., Bradley, M. M., & Lang, P. J. (2013). Perceptual processing of natural scenes at rapid rates: Effects of complexity, content, and emotional arousal. *Cognitive, Affective and Behavioral Neuroscience*, *13*(4), 860–868. https://doi.org/10.3758/s13415-013-0179-1

Lugli, L., Baroni, G., Gianelli, C., Borghi, A. M., & Nicoletti, R. (2012). Self, others, objects: How this triadic interaction modulates our behavior. *Memory and Cognition*, *40*(8), 1373–1386. https://doi.org/10.3758/s13421-012-0218-0

Lund, K., & Burgess, C. (1996). Producing high-dimensional semantic spaces from lexical co-occurrence. *Behavior Research Methods, Instruments, and Computers*, *28*(2), 203–208. https://doi.org/10.3758/BF03204766

Lundqvist, D., Flykt, A., & Öhman. A. (1998). The Karolinska directed emotional faces - KDEF. *CD ROM from Department of Clinical Neuroscience, Psychology Section, Karolinska Institutet*.

Macedonia, M. (2015). Learning styles and vocabulary acquisition in second language: How the brain learns. *Frontiers in Psychology*, *6*(NOV), 1800. https://doi.org/10.3389/fpsyg.2015.01800

Maris, E., & Oostenveld, R. (2007). Nonparametric statistical testing of EEG- and MEG-data. *Journal of Neuroscience Methods*, *164*(1), 177–190. https://doi.org/10.1016/j.jneumeth.2007.03.024

Markham, R., & Adams, K. (1992). The effect of type of task on children's identification of facial expressions. *Journal of Nonverbal Behavior*, *16*(1), 21–39. https://doi.org/10.1007/BF00986877

Markowitsch, H. J., Vandekerckhove, M. M. P., Lanfermann, H., & Russ, M. O. (2003). Engagement of lateral and medial prefrontal areas in the ecphory of sad and happy autobiographical memories. *Cortex*, *39*(4–5), 643–665. https://doi.org/10.1016/S0010-9452(08)70858-X

Marsh, P., Beauchaine, T. P., & Williams, B. (2008). Dissociation of sad facial expressions and autonomic nervous system responding in boys with disruptive behavior disorders. *Psychophysiology*, *45*(1), 100–110. https://doi.org/10.1111/j.1469-8986.2007.00603.x

Mattavelli, G., Sormaz, M., Flack, T., Asghar, A. U. R., Siyan, F., Frey, J., Manssuer, L., Usten, D., Young, A. W., & Andrews, T. J. (2014). Neural responses to facial expressions support the role of the amygdala in processing threat. *Social Cognitive & Affective Neuroscience*, *9*(11), 1684–1689. https://doi.org/10.1093/scan/nst162

Mégevand, P., Groppe, D. M., Goldfinger, M. S., Hwang, S. T., Kingsley, P. B., Davidesco, I., & Mehta, A. D. (2014). Seeing scenes: Topographic visual hallucinations evoked by direct electrical stimulation of the parahippocampal place area. *Journal of Neuroscience*, *34*(16), 5399–5405. https://doi.org/10.1523/JNEUROSCI.5202-13.2014

Meigs, A. S. (1978). A Papuan perspective on pollution. *Man*, *13*(2), 304–318. https://doi.org/10.2307/2800251

Mestres Missé, A. (2008). *Neural correlates of word learning and meaning acquisition*. Universitat de Barcelona.

Mikulincer, M., & Florian, V. (1997). A Cognitive-Relational Approach to Emotions—The Appraisal and Coping Components of Sadness, Shame, Guilt, Jealousy, and Disgust. *Imagination, Cognition and Personality*, *16*(3), 263–279. https://doi.org/10.2190/00l2-tl35-6w2y-e9m1

Moseley, R., Carota, F., Hauk, O., Mohr, B., & Pulvermüller, F. (2012). A role for motor system in binding abstract emotional meaning. *Cerebral Cortex*, *22*(7), 1634–1647.

Mouilso, E., Glenberg, A. M., Havas, D., & Lindeman, L. M. (2007). Differences in action tendencies distinguish anger and sadness after comprehension of emotional sentences. *Proceedings of the Annual Meeting of the Cognitive Science Society*, *29*(29), 1325–1330.

Mühlberger, A., Wieser, M. J., Herrmann, M. J., Weyers, P., Tröger, C., & Pauli, P. (2009). Early cortical processing of natural and artificial emotional faces differs between lower and higher socially anxious persons. *Journal of Neural Transmission*, *116*(6), 735–746. https://doi.org/10.1007/s00702-008-0108-6

Nagy, W. E., Anderson, R. C., & Herman, P. A. (1987). Learning word meanings from context during normal reading. *American Educational Research Journal*, *24*(2), 237–270. https://doi.org/10.3102%2F00028312024002237

Nakic, M., Smith, B. W., Busis, S., Vythilingam, M., & Blair, R. J. R. (2006). The impact of affect and frequency on lexical decision: The role of the amygdala and inferior frontal cortex. *NeuroImage*, *31*(4), 1752–1761. https://doi.org/10.1016/j.neuroimage.2006.02.022

Namba, S., Kagamihara, T., Miyatani, M., & Nakao, T. (2017). Spontaneous facial expressions reveal new action units for the sad experiences. *Journal of Nonverbal Behavior*, *41*(3), 203–220. https://doi.org/10.1007/s10919-017-0251-6

Naumann, E., Bartussek, D., Dierich, O., & Laufer, M. E. (1992). Assessing cognitive and affective information processing functions of the brain by means of the late positive complex of the event-related potential. *Journal of Psychophysiology*, *6*(4), 285–298. https://psycnet.apa.org/record/1993-32496-001

Niedenthal, P. M. (2007). Embodying emotion. *Science, 316*(5827), 1002–1005. https://doi.org/10.1126/science.1136930

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review*, *9*(3), 184–211. https://doi.org/10.1207/s15327957pspr0903_1

Niedenthal, P. M., Brauer, M., Robin, L., & Innes-Ker, Å. H. (2002). Adult attachment and the perception of facial expression of emotion. *Journal of Personality and Social Psychology*, *82*(3), 419–433. https://doi.org/10.1037/0022-3514.82.3.419

Niida, R., & Mimura, M. (2017). The center of sadness, pain, and recognition. *Brain and Nerve, 69*(4), 417-426. https://doi.org/10.11477/mf.1416200759

Nordström, H., & Wiens, S. (2012). Emotional event-related potentials are larger to figures than scenes but are similarly reduced by inattention. *BMC Neuroscience*, *13*(1), 1–10. https://doi.org/10.1186/1471-2202-13-49

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: Detecting the snake in the grass. *Journal of Experimental Psychology: General*, *130*(3), 466–478. https://doi.org/10.1037/0096-3445.130.3.466

Oostenveld, R., Fries, P., Maris, E., & Schoffelen, J.-M. (2011). FieldTrip: Open Source Software for Advanced Analysis of MEG, EEG, and Invasive Electrophysiological Data. *Computational Intelligence and Neuroscience*, *2011*. https://doi.org/10.1155/2011/156869

Opitz, B., & Degner, J. (2012). Emotionality in a second language: It's a matter of time. *Neuropsychologia*, *50*(8), 1961–1967. https://doi.org/10.1016/j.neuropsychologia.2012.04.021

Ots, T. (1990). The angry liver, the anxious heart and the melancholy spleen - The phenomenology of perceptions in Chinese culture. *Culture, Medicine and Psychiatry*, *14*(1), 21–58. https://doi.org/10.1007/BF00046703

Padmala, S., Bauer, A., & Pessoa, L. (2011). Negative emotion impairs conflict-driven executive control. *Frontiers in Psychology*, *2*(AUG), 192. https://doi.org/10.3389/fpsyg.2011.00192

Palazova, M., Mantwill, K., Sommer, W., & Schacht, A. (2011). Are effects of emotion in single words non-lexical? Evidence from event-related brain potentials. *Neuropsychologia*, *49*(9), 2766–2775. https://doi.org/10.1016/j.neuropsychologia.2011.06.005

Pascual-Marqui, R. D. (2002). Standardized low-resolution brain electromagnetic tomography (sLORETA): Technical details. *Methods and Findings in Experimental and Clinical Pharmacology*, *24*(SUPPL. D), 5–12.

Pasfield-Neofitou, S., Huang, H., & Grant, S. (2015). Lost in second life: virtual embodiment and language learning via multimodal communication. *Educational Technology Research and Development*, *63*(5), 709–726. https://doi.org/10.1007/s11423-015-9384-7

Pavlenko, A. (2012). Affective processing in bilingual speakers: Disembodied cognition? *International Journal of Psychology*, *47*(6), 405–428. https://doi.org/10.1080/00207594.2012.743665

Phan, K. L., Wager, T., Taylor, S. F., & Liberzon, I. (2002). Functional neuroanatomy of emotion: A meta-analysis of emotion activation studies in PET and fMRI. *NeuroImage, 16*(2), 331–348. https://doi.org/10.1006/nimg.2002.1087

Phillips, M. L., Young, A. W., Scott, S. K., Calder, A. J., Andrew, C., Giampietro, V., Williams, S. C. R., Bullmore, E. T., Brammer, M., & Gray, J. A. (1998). Neural responses to facial and vocal expressions of fear and disgust. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *265*(1408), 1809–1817. https://doi.org/10.1098/rspb.1998.0506

Phillips, M. L., Young, A. W., Senior, C., Brammer, M., Andrew, C., Calder, A. J., Bullmore, E. T., Perrett, D. I., Rowland, D., Williams, S. C. R., Gray, J. A., & David, A. S. (1997). A specific neural substrate for perceiving facial expressions of disgust. *Nature*, *389*(6650), 495–498. https://doi.org/10.1038/39051

Phillips, Mary L., Williams, L. M., Heining, M., Herba, C. M., Russell, T., Andrew, C., Bullmore, E. T., Brammer, M. J., Williams, S. C. R., Morgan, M., Young, A. W., & Gray, J. A. (2004). Differential neural responses to overt and covert presentations of facial expressions of fear and disgust. *NeuroImage*, *21*(4), 1484–1496. https://doi.org/10.1016/j.neuroimage.2003.12.013

Ponz, A., Montant, M., Liégeois-Chauvel, C., Silva, C., Braun, M., Jacobs, A. M., & Ziegler, J. C. (2014). Emotion processing in words: A test of the neural re-use hypothesis using surface and intracranial EEG. *Social Cognitive and Affective Neuroscience*, *9*(5), 619–627. https://doi.org/10.1093/scan/nst034

Pulvermüller, F. (2005). Brain mechanisms linking language and action. In *Nature Reviews Neuroscience* (Vol. 6, Issue 7, pp. 576–582). Nature Publishing Group. https://doi.org/10.1038/nrn1706

Ramirez-Mahaluf, J. P., Perramon, J., Otal, B., Villoslada, P., & Compte, A. (2018). Subgenual anterior cingulate cortex controls sadness-induced modulations of cognitive and emotional network hubs. *Scientific Reports*, *8*(1), 8566–8566. https://doi.org/10.1038/s41598-018-26317-4

Reisenzein, R., Studtmann, M., & Horstmann, G. (2013). Coherence between emotion and facial expression: Evidence from laboratory experiments. *Emotion Review*, *5*(1), 16–23. https://doi.org/10.1177/1754073912457228

Ritz, T., Thöns, M., Fahrenkrug, S., & Dahme, B. (2005). Airways, respiration, and respiratory sinus arrhythmia during picture viewing. *Psychophysiology*, *42*(5), 568–578. https://doi.org/10.1111/j.1469-8986.2005.00312.x

Rossion, B., Caldara, R., Seghier, M., Schuller, A. M., Lazeyras, F., & Mayer, E. (2003). A network of occipito-temporal face-sensitive areas besides the right middle fusiform gyrus is necessary for normal face processing. *Brain*, *126*(11), 2381–2395. https://doi.org/10.1093/brain/awg241

Rozin, P., & Fallon, A. E. (1987). A Perspective on Disgust. *Psychological Review*, *94*(1), 23–41. https://doi.org/10.1037/0033-295X.94.1.23

Rozin, P., & Haidt, J. (2013). The domains of disgust and their origins: Contrasting biological and cultural evolutionary accounts. *Trends in Cognitive Sciences, 17*(8), 367–368. https://doi.org/10.1016/j.tics.2013.06.001

Rozin, P., Haidt, J., & McCauley, C. R. (2008). Disgust. In M. Lewis, J. M. Haviland-Jones, & L. F. Barrett (Eds.). In *Handbook of emotions* (pp. 757–776). The Guilford Press. https://psycnet.apa.org/record/2008-07784-047

Rozin, P., Lowery, L., & Ebert, R. (1994). Varieties of disgust faces and the structure of disgust. *Journal of Personality and Social Psychology*, *66*(5), 870–881. https://doi.org/10.1037/0022-3514.66.5.870

Rozin, P., Millman, L., & Nemeroff, C. (1986). Operation of the Laws of Sympathetic Magic in Disgust and Other Domains. *Journal of Personality and Social Psychology*, *50*(4), 703–712. https://doi.org/10.1037/0022-3514.50.4.703

Rozin, P., Nemeroff, C., Horowitz, M., Gordon, B., & Voet, W. (1995). The borders of the self: Contamination sensitivity and potency of the body apertures and other body parts. *Journal of Research in Personality*, *29*(3), 318–340. https://doi.org/10.1006/jrpe.1995.1019

Rozin, Paul, & Fallon, A. E. (1987). A Perspective on Disgust. *Psychological Review*, *94*(1), 23–41. https://doi.org/10.1037/0033-295X.94.1.23

Rozin, Paul, & Haidt, J. (2013). The domains of disgust and their origins: Contrasting biological and cultural evolutionary accounts. *Trends in Cognitive Sciences*, 17(8), 367–368. https://doi.org/10.1016/j.tics.2013.06.001

Rozin, Paul, Lowery, L., & Ebert, R. (1994). Varieties of disgust faces and the structure of disgust. *Journal of Personality and Social Psychology*, *66*(5), 870–881. https://doi.org/10.1037/0022-3514.66.5.870

Russell, J. A., Bachorowski, J.-A., & Fernández-Dols, J.-M. (2003). Facial and vocal expressions of emotion. *Annual Review of Psychology*, *54*(1), 329–349. https://doi.org/10.1146/annurev.psych.54.101601.145102

Sambataro, F., Dimalta, S., di Giorgio, A., Taurisano, P., Blasi, G., Scarabino, T., Giannatempo, G., Nardini, M., & Bertolino, A. (2006). Preferential responses in amygdala and insula during presentation of facial contempt and disgust. *European Journal of Neuroscience*, *24*(8), 2355–2362. https://doi.org/10.1111/j.1460-9568.2006.05120.x

Sass, S. M., Heller, W., Stewart, J. L., Silton, R. L., Edgar, J. C., Fisher, J. E., & Miller, G. A. (2010). Time course of attentional bias in anxiety: Emotion and gender specificity. *Psychophysiology*, *47*(2), 247–259. https://doi.org/10.1111/j.1469-8986.2009.00926.x

Schacht, A., & Sommer, W. (2009). Emotions in word and face processing: Early and late cortical responses. *Brain and Cognition*, *69*(3), 538–550. https://doi.org/10.1016/j.bandc.2008.11.005

Schacht, A., & Sommer, W. (2009). Time course and task dependence of emotion effects in word processing. *Cognitive, Affective and Behavioral Neuroscience*, *9*(1), 28–43. https://doi.org/10.3758/CABN.9.1.28

Schienle, A., Übel, S., & Wabnegger, A. (2017). When opposites lead to the same: a direct comparison of explicit and implicit disgust regulation via fMRI. *Social Cognitive and Affective Neuroscience*, *12*(3), 445–451. https://europepmc.org/article/pmc/pmc5390737

Schupp, H. T., Flaisch, T., Stockburger, J., & Junghöfer, M. (2006). Emotion and attention: event-related brain potential studies. *Progress in Brain Research*, *156*, 31–51. https://doi.org/10.1016/S0079-6123(06)56002-9

Schupp, H. T., Junghöfer, M., Öhman, A., Weike, A. I., Stockburger, J., & Hamm, A. O. (2004). The facilitated processing of threatening faces: An ERP analysis. *Emotion*, *4*(2), 189–200. https://doi.org/10.1037/1528-3542.4.2.189

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2003). Attention and emotion: An ERP analysis of facilitated emotional stimulus processing. *NeuroReport*, *14*(8), 1107–1110. https://doi.org/10.1097/00001756-200306110-00002

Schupp, H. T., Junghöfer, M., Weike, A. I., & Hamm, A. O. (2004). The selective processing of briefly presented affective pictures: An ERP analysis. *Psychophysiology*, *41*(3), 441–449. https://doi.org/10.1111/j.1469-8986.2004.00174.x

Schupp, H. T., Stockburger, J., Codispoti, M., Jungh??fer, M., Weike, A. I., & Hamm, A. O. (2006). Stimulus novelty and emotion perception: the near absence of habituation in the visual cortex. *NeuroReport*, *17*(4), 365–369. https://doi.org/10.1097/01.wnr.0000203355.88061.c6

Scott, G. G., O’Donnell, P. J., Leuthold, H., & Sereno, S. C. (2009). Early emotion word processing: Evidence from event-related potentials. *Biological Psychology*, *80*(1), 95–104. https://doi.org/10.1016/j.biopsycho.2008.03.010

Sheikh, N. A., & Titone, D. (2016). The embodiment of emotional words in a second language: An eye-movement study. *Cognition and Emotion*, *30*(3), 488–500. https://doi.org/10.1080/02699931.2015.1018144

Silani, G., Lamm, C., Ruff, C. C., & Singer, T. (2013). Right supramarginal gyrus is crucial to overcome emotional egocentricity bias in social judgments. *Journal of Neuroscience*, *33*(39), 15466–15476. https://doi.org/10.1523/JNEUROSCI.1488-13.2013

Sinha, R., Lovallo, W. R., & Parsons, O. A. (1992). Cardiovascular differentiation of emotions. *Psychosomatic Medicine*, *54*(4), 422–435. https://doi.org/10.1097/00006842-199207000-00005

Spielberger, C. D., & Reheiser, E. C. (2010). The Nature and Measurement of Anger. In M. Potegal, G. Stemmler, C. Spielberger (Eds.), *International Handbook of Anger* (pp. 403–412). New York: Springer. https://doi.org/10.1007/978-0-387-89676-2_23

Spiridon, M., Fischl, B., & Kanwisher, N. (2006). Location and spatial profile of category-specific regions in human extrastriate cortex. *Human Brain Mapping*, *27*(1), 77–89. https://doi.org/10.1002/hbm.20169

Staats, A. W., & Staats, C. K. (1959). Meaning and m: Correlated but separate. *Psychological Review*, *66*(2), 136–144. https://doi.org/10.1037/h0047970

Staats, C. K., & Staats, A. W. (1957). Meaning established by classical conditioning. *Journal of Experimental Psychology*, *54*(1), 74–80. https://doi.org/10.1037/h0048859

Stark, R., Walter, B., Schienle, A., & Vaitl, D. (2005). Psychophysiological correlates of disgust and disgust sensitivity. *Journal of Psychophysiology*, *19*(1), 50–60. https://doi.org/10.1027/0269-8803.19.1.50

Stenberg, G., Wiking, S., & Dahl, M. (1998). Judging words at face value: Interference in a word processing task reveals automatic processing of affective facial expressions. *Cognition and Emotion*, *12*(6), 755–782. https://doi.org/10.1080/026999398379420

Straube, T., Sauer, A., & Miltner, W. H. R. (2011). Brain activation during direct and indirect processing of positive and negative words. *Behavioural Brain Research*, *222*(1), 66–72. https://doi.org/10.1016/j.bbr.2011.03.037

Suzuki, A., & Akiyama, H. (2013). Cognitive aging explains age-related differences in face-based recognition of basic emotions except for anger and disgust. *Aging, Neuropsychology, and Cognition*, *20*(3), 253–270. https://doi.org/10.1080/13825585.2012.692761

Taylor, J. S. H., Rastle, K., & Davis, M. H. (2013). Can cognitive models explain brain activation during word and pseudoword reading? A meta-analysis of 36 neuroimaging studies. *Psychological Bulletin*, *139*(4), 766–791. https://doi.org/10.1037/a0030266

Tsai, J. L., Simeonova, D. I., & Watanabe, J. T. (2004). Somatic and social: Chinese Americans talk about emotion. *Personality and Social Psychology Bulletin*, 30(9), 1226–1238. https://doi.org/10.1177/0146167204264014

Tung, M. P. M. (1994). Symbolic meanings of the body in Chinese culture and "somatization." *Culture, Medicine and Psychiatry*, *18*(4), 483–492. https://doi.org/10.1007/BF01565850

Valaki, C. E., Maestu, F., Simos, P. G., Zhang, W., Fernandez, A., Amo, C. M., Ortiz, T. M., & Papanicolaou, A. C. (2004). Cortical organization for receptive language functions in Chinese, English, and Spanish: A cross-linguistic MEG study. *Neuropsychologia*, *42*(7), 967–979. https://doi.org/10.1016/j.neuropsychologia.2003.11.019

Vicari, S., Reilly, J. S., Pasqualetti, P., Vizzotto, A., & Caltagirone, C. (2000). Recognition of facial expressions of emotions in school-age children: the intersection of perceptual and semantic categories. *Acta Paediatrica (Oslo, Norway : 1992)*, *89*(7), 836–845. http://www.ncbi.nlm.nih.gov/pubmed/10943968

Viol, K., Aas, B., Kastinger, A., Kronbichler, M., Schöller, H. J., Reiter, E.-M., Said-Yürekli, S., Kronbichler, L., Kravanja-Spannberger, B., Stöger-Schmidinger, B., Aichhorn, W., & Schiepek, G. K. (2019). Erroneously Disgusted: fMRI Study Supports Disgust-Related Neural Reuse in Obsessive-Compulsive Disorder (OCD). *Frontiers in Behavioral Neuroscience*, *13*, 81. https://doi.org/10.3389/fnbeh.2019.00081

Wada, Y., & Yamamoto, T. (2001). Selective impairment of facial recognition due to a hematoma restricted to the right fusiform and lateral occipital region. *Journal of Neurology Neurosurgery and Psychiatry*, *71*(2), 254–257. https://doi.org/10.1136/jnnp.71.2.254

Wager, T. D., & Smith, E. E. (2003). Neuroimaging studies of working memory: A meta-analysis. *Cognitive, Affective and Behavioral Neuroscience, 3*(4), 255–274. https://doi.org/10.3758/CABN.3.4.255

Walther, E. (2002). Guilty by mere association: evaluative conditioning and the spreading attitude effect. *Journal of Personality and Social Psychology*, *82*(6), 919–934. https://doi.org/10.1037/0022-3514.82.6.919

Wang, H., Chang, R. B., & Li, Y. S. (1986). *Modern Chinese frequency dictionary*. Beijing Language Institute.

Wang, H., Yan, X., & Guo, H. (2019). Visualizing the knowledge domain of embodied language cognition: A bibliometric review. *Digital Scholarship in the Humanities*, *34*(1), 21–31. https://doi.org/10.1093/llc/fqy010

Wang, L., Bastiaansen, M., Yang, Y., & Hagoort, P. (2013). ERP evidence on the interaction between information structure and emotional salience of words. *Cognitive, Affective and Behavioral Neuroscience*, *13*(2), 297–310. https://doi.org/10.3758/s13415-012-0146-2

Ware, J., Jain, K., Burgess, I., & Davey, G. C. L. (1994). Disease-avoidance model: Factor analysis of common animal fears. *Behaviour Research and Therapy*, *32*(1), 57–63. https://doi.org/10.1016/0005-7967(94)90084-1

Webb, C. A., Olson, E. A., Killgore, W. D. S., Pizzagalli, D. A., Rauch, S. L., & Rosso, I. M. (2018). Rostral Anterior Cingulate Cortex Morphology Predicts Treatment Response to Internet-Based Cognitive Behavioral Therapy for Depression. *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging*, *3*(3), 255–262. https://doi.org/10.1016/j.bpsc.2017.08.005

Webb, K., & Davey, G. C. L. (1992). Disgust sensitivity and fear of animals: Effect of exposure to violent or revulsive material. *Anxiety, Stress, & Coping*, *5*(4), 329–335. https://doi.org/10.1080/10615809208248369

Wicker, B., Keysers, C., Plailly, J., Royet, J. P., Gallese, V., & Rizzolatti, G. (2003). Both of us disgusted in my insula: The common neural basis of seeing and feeling disgust. *Neuron*, *40*(3), 655–664. https://doi.org/10.1016/S0896-6273(03)00679-2

Wittgenstein, L. (1958). *Philosophical Investigations*. New Jersey: Blackwell.

Woody, S. R., & Teachman, B. A. (2006). Intersection of disgust and fear: Normative and pathological views. *Clinical Psychology: Science and Practice*, *7*(3), 291–311. https://doi.org/10.1093/clipsy.7.3.291

Wright, P., He, G., Shapira, N. A., Goodman, W. K., & Liu, Y. (2004). Disgust and the insula: fMRI responses to pictures of mutilation and contamination. *NeuroReport*, *15*(15), 2347–2351. https://doi.org/10.1097/00001756-200410250-00009

Xie, M., Yang, Q., & Wang, Q. (2016). The P200 component in lexical processing. *Advances in Psychology*, *6*(2), 114–120. https://doi.org/10.12677/ap.2016.62015

Yan, C., & Dillard, J. P. (2010). Emotion inductions cause changes in activation levels of the behavioural inhibition and approach systems. *Personality and Individual Differences*, *48*(5), 676–680. https://doi.org/10.1016/j.paid.2009.12.002

Yao, Z., Wu, J., Zhang, Y., & Wang, Z. (2017). Norms of valence, arousal, concreteness, familiarity, imageability, and context availability for 1,100 Chinese words. *Behavior Research Methods*, *49*(4), 1374–1385. https://doi.org/10.3758/s13428-016-0793-2

Yi, S., He, W., Zhan, L., Qi, Z., Zhu, C., Luo, W., & Li, H. (2015). Emotional noun processing: An ERP study with rapid serial visual presentation. *PLoS ONE*, *10*(3). https://doi.org/10.1371/journal.pone.0118924

Yu, N. (2002). Body and emotion: Body parts in Chinese expression of emotion. *Pragmatics and Cognition*, *10*(1–2), 341–367. https://doi.org/10.1075/pc.10.12.14yu

Zhang, D., He, W., Wang, T., Luo, W., Zhu, X., Gu, R., Li, H., & Luo Y. (2014). Three stages of emotional word processing: an ERP study with rapid serial visual presentation. *Social Cognitive and Affective Neuroscience*, *9*(12), 1897–1903.

Zhang, D, Liu, Y., Wang, L., Ai, H., & Luo, Y. (2017). Mechanisms for attentional modulation by threatening emotions of fear, anger, and disgust. *Cognitive, Affective and Behavioral Neuroscience*, *17*(1), 198–210. https://doi.org/10.3758/s13415-016-0473-9

Zhang, Q., Zhang, J. X., & Kong, L. (2009). An ERP study on the time course of phonological and semantic activation in Chinese word recognition. *International Journal of Psychophysiology*, *73*(3), 235–245. https://doi.org/10.1016/j.ijpsycho.2009.04.001

Zhao, S., Xiang, Y., Xie, J., Ye, Y., Li, T., & Mo, L. (2017). The Positivity Bias Phenomenon in Face Perception Given Different Information on Ability. *Frontiers in Psychology*, *8*(APR), 570. https://doi.org/10.3389/fpsyg.2017.00570

Zubieta, J. K., Ketter, T. A., Bueller, J. A., Xu, Y., Kilbourn, M. R., Young, E. A., & Koeppe, R. A. (2003). Regulation of Human Affective Responses by Anterior Cingulate and Limbic μ-Opioid Neurotransmission. Archives of General Psychiatry, 60(11), 1145–1153. https://doi.org/10.1001/archpsyc.60.11.1145

Zwaan, R. A. (2014). Embodiment and language comprehension: Reframing the discussion. In *Trends in Cognitive Sciences* (Vol. 18, Issue 5, pp. 229–234). Elsevier Ltd. https://doi.org/10.1016/j.tics.2014.02.008

APPENDICES

Appendix 1

Experiment 1. Normative study questionnaires

请阅读下列词语，并判定该词语所引发的厌恶程度：

1 表示阅读该词语后完全没有恶心、厌恶、想要远离的感觉；

5 表示阅读该词语后感到比较恶心、厌恶，想要远离；

9 表示阅读该词语后感到非常恶心、厌恶，非常想要远离。

请不要在同一词语上停留太长时间，请根据阅读词语后的第一反应进行评定。

Please read the following words and rate their extents of disgust:

1 refers to not feel sick, disgusted, and the intention to withdraw at all;

5 refers to feel moderately sick, disgusted, and the intention to withdraw;

9 refers to feel extremely sick, disgusted, and the intention to withdraw.

Please do not dwell on each word for too long. Rate each word based on your most intuitive feelings.

肮脏 *dirtiness* 1 2 3 4 5 6 7 8 9

苍蝇 *fly* 1 2 3 4 5 6 7 8 9

老鼠 *mouse* 1 2 3 4 5 6 7 8 9

细菌 *germ* 1 2 3 4 5 6 7 8 9

厕所 *bathroom* 1 2 3 4 5 6 7 8 9

鼻涕 *snot* 1 2 3 4 5 6 7 8 9

痤疮 *acne* 1 2 3 4 5 6 7 8 9

毒瘤 *malignant tumor* 1 2 3 4 5 6 7 8 9

毒蛇 *viper* 1 2 3 4 5 6 7 8 9

粪便 *feces* 1 2 3 4 5 6 7 8 9

干尸 *mummification* 1 2 3 4 5 6 7 8 9

骨灰 *bone ash* 1 2 3 4 5 6 7 8 9

溃疡 *ulcer* 1 2 3 4 5 6 7 8 9

泥泞 *miriness* 1 2 3 4 5 6 7 8 9

脓包 *pustule* 1 2 3 4 5 6 7 8 9

雀斑 *freckle* 1 2 3 4 5 6 7 8 9

伤疤 *scar* 1 2 3 4 5 6 7 8 9

尸骨 *skeleton* 1 2 3 4 5 6 7 8 9

虱子 *louse* 1 2 3 4 5 6 7 8 9

污垢 *dirt* 1 2 3 4 5 6 7 8 9

蝎子 *scorpion* 1 2 3 4 5 6 7 8 9

血迹 *bloodstain* 1 2 3 4 5 6 7 8 9

遗骸 *remains* 1 2 3 4 5 6 7 8 9

病毒 *virus* 1 2 3 4 5 6 7 8 9

僵尸 *zombie* 1 2 3 4 5 6 7 8 9

尸体 *corpse* 1 2 3 4 5 6 7 8 9

蟑螂 *cockroach* 1 2 3 4 5 6 7 8 9

瘟疫 *plague* 1 2 3 4 5 6 7 8 9

肛门 *anus* 1 2 3 4 5 6 7 8 9

感染 *infection* 1 2 3 4 5 6 7 8 9

呕吐 *vomit* 1 2 3 4 5 6 7 8 9

截肢 *amputation* 1 2 3 4 5 6 7 8 9

蜘蛛 *spider* 1 2 3 4 5 6 7 8 9

痰桶 *spitton* 1 2 3 4 5 6 7 8 9

疱疹 *herpes* 1 2 3 4 5 6 7 8 9

油脂 *grease* 1 2 3 4 5 6 7 8 9

害虫 *insect* 1 2 3 4 5 6 7 8 9

小便 *piss* 1 2 3 4 5 6 7 8 9

废料 *waste* 1 2 3 4 5 6 7 8 9

污垢 *filth* 1 2 3 4 5 6 7 8 9

蛔虫 *roundworm* 1 2 3 4 5 6 7 8 9

直肠 *rectum* 1 2 3 4 5 6 7 8 9

肉瘤 *sarcoma* 1 2 3 4 5 6 7 8 9

浓痰 *phlegm* 1 2 3 4 5 6 7 8 9

腐烂 *rot* 1 2 3 4 5 6 7 8 9

痢疾 *dysentery* 1 2 3 4 5 6 7 8 9

马桶 *toilet* 1 2 3 4 5 6 7 8 9

大便 *excrement* 1 2 3 4 5 6 7 8 9

疾病 *illness* 1 2 3 4 5 6 7 8 9

尿液 *urine* 1 2 3 4 5 6 7 8 9

肥料 *fertilizer* 1 2 3 4 5 6 7 8 9

肠子 *intestine* 1 2 3 4 5 6 7 8 9

黏液 *mucus* 1 2 3 4 5 6 7 8 9

泥浆 *slurry* 1 2 3 4 5 6 7 8 9

肿瘤 *tumor* 1 2 3 4 5 6 7 8 9

蚊子 *mosquito* 1 2 3 4 5 6 7 8 9

蛤蟆 *toad* 1 2 3 4 5 6 7 8 9

蜈蚣 *centipede* 1 2 3 4 5 6 7 8 9

狐臭 *hircus* 1 2 3 4 5 6 7 8 9

臭虫 *cimicid* 1 2 3 4 5 6 7 8 9

口水 *saliva* 1 2 3 4 5 6 7 8 9

痔疮 *hemorrhoids* 1 2 3 4 5 6 7 8 9

油腻 *greasiness* 1 2 3 4 5 6 7 8 9

霉菌 *mould* 1 2 3 4 5 6 7 8 9

狗屎 *dogshit* 1 2 3 4 5 6 7 8 9

恶臭 *stink* 1 2 3 4 5 6 7 8 9

裸体 *nudity* 1 2 3 4 5 6 7 8 9

便秘 *constipation* 1 2 3 4 5 6 7 8 9

汗渍 *sweat stain* 1 2 3 4 5 6 7 8 9

肥肉 *fat meat* 1 2 3 4 5 6 7 8 9

耳屎 *earwax* 1 2 3 4 5 6 7 8 9

腹泻 *diarrhea* 1 2 3 4 5 6 7 8 9

触角 *tentacle* 1 2 3 4 5 6 7 8 9

蝗虫 *locust* 1 2 3 4 5 6 7 8 9

脑浆 *brains* 1 2 3 4 5 6 7 8 9

湿疹 *eczema* 1 2 3 4 5 6 7 8 9

头屑 *dandruff* 1 2 3 4 5 6 7 8 9

脓肿 *abscess* 1 2 3 4 5 6 7 8 9

蛆虫 *maggot* 1 2 3 4 5 6 7 8 9

粉刺 *pimple* 1 2 3 4 5 6 7 8 9

便池 *urinal* 1 2 3 4 5 6 7 8 9

口臭 *halitosis* 1 2 3 4 5 6 7 8 9

请阅读下列词语，并判定该词语的以下维度：

愉悦度

是指愉快或不愉快的情绪体验及其强度，其得分从 1（非常不愉快）到 9（非常愉快）之间变化。

唤醒度

指与情绪活动相伴随的机体唤醒程度，其得分从 1（不兴奋，非常没精神）到 9（非常提神和兴奋）之间变化。

表象性

是指在你的脑海里，你能否容易地想象出这个词表达的形象,其得分从 1（非常难）到 9（非常容易）之间变化。

例如：

“婚礼”这个词，读完后通常有比较愉悦的心情（愉悦度），心情比较激动（唤醒度），脑海里能够比较容易的想象出婚礼的场景（表象性），那么这几个维度的评定等级通常都在 6 以上。而“事实”这个词，读完后感到情绪上没有明显变化，心情也比较平静，很难想象出这个词想表达的形象，那么对该词愉悦度和唤醒度评定通常在 5 分左右，表象性低于 3。

读完一个词汇的感受是因人而异的，没有对错之分，因此评定的时候依据自己的第一感觉即可。

Please read the following words and rate the corresponding variables:

Valence

It refers to positive or negative emotional experience brought by the word and its intensity, which scales from 1 (extremely negative) to 9 (extremely positive).

Arousal

It refers to how much the word arouses your emotional experience, which scales from 1 (not excited and not arousing at all) to 9 (extremely excited and arousing).

Imageablitity

It refers to whether you could easily imagine the object or feeling denoted by the word, which scales from 1 (extremely difficult) to 9 (extremely easy).

For example:

The word "wedding" usually gives you a positive feeling (valence), fairly arouses you (arousal), and is easy for you to imagine what a wedding is like (imageability). In this case, the ratings of these variables are likely to be above 6. The word "fact" on the other hand, you feel neither positive nor negative after reading it, you do not feel very emotional, and it is difficult for you to imagine a specific object or feeling denoted by it. In this case, the ratings for valence and arousal are likely to be around 5 and imageability below 3.

The feeling after reading a word varies from person to person. There is no right or wrong answer for this questionnaire. Therefore, please rate the words based on your most intuitive feelings.

细菌 *germ* 愉悦度 1 2 3 4 5 6 7 8 9 *Valence* 唤醒度 1 2 3 4 5 6 7 8 9 *Arousal* 表象性 1 2 3 4 5 6 7 8 9 *Imageability*	**厕所 *bathroom*** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
溃疡 *ulcer* 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**雀斑 *freckle*** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
蝎子 scorpion 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**感染 infection** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
截肢 amputation 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**小便 piss** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
直肠 rectum 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**马桶 toilet** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
尿液 urine 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9	**肿瘤 tumor** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9

表象性 1 2 3 4 5 6 7 8 9	表象性 1 2 3 4 5 6 7 8 9
口水 saliva 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**霉菌 mould** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9

便秘 constipation 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**肥肉 fat meat** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
腹泻 diarrhea 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**头屑 dandruff** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
苍蝇 fly 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**鼻涕 snot** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
毒蛇 viper 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**遗骸 remains** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
病毒 virus 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**呕吐 vomit** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
肉瘤 sarcoma 愉悦度 1 2 3 4 5 6 7 8 9	**黏液 mucus** 愉悦度 1 2 3 4 5 6 7 8 9

唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
蛤蟆 toad 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**蜈蚣 centipede** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
湿疹 eczema 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**粉刺 pimple** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
口臭 halitosis 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**老鼠 mouse** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
痤疮 acne 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**毒瘤 malignant tumor** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
骨灰 bone ash 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**尸骨 skeleton** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
虱子 louse 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**僵尸 zombie** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
尸体 corpse 愉悦度 1 2 3 4 5 6 7 8 9	**蟑螂 cockroach** 愉悦度 1 2 3 4 5 6 7 8 9

唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
肛门 anus 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**疱疹 herpes** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
蛔虫 roundworm 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**浓痰 phlegm** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
腐烂 rot 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**痢疾 dysentery** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
大便 excrement 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**臭虫 cimicid** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
痔疮 hemorrhoids 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**狗屎 dogshit** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
恶臭 stink 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**脑浆 brains** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
脓肿 abscess 愉悦度 1 2 3 4 5 6 7 8 9	**便池 urinal** 愉悦度 1 2 3 4 5 6 7 8 9

唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
粪便 feces 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**干尸 mummification** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
脓包 pustule 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**瘟疫 plague** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
痰桶 spittoon 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**狐臭 hircus** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
蛆虫 maggot 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	**肠子 intestine** 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9
耳屎 earwax 愉悦度 1 2 3 4 5 6 7 8 9 唤醒度 1 2 3 4 5 6 7 8 9 表象性 1 2 3 4 5 6 7 8 9	

Appendix 2

Experiment 1. Selected Stimuli

Disgust-relatd words

浓痰 phlegm 厕所 bathroom 痤疮 acne 小便 piss 霉菌 mould 肥肉 fat meat

口水 saliva 肿瘤 tumor 口臭 halitosis 呕吐 vomit 大便 feces 腹泻 diarrhea

尿液 urine 头屑 dandruff 脓包 pustule 病毒 virus 便秘 constipation 毒蛇 viper

骨灰 bone ash 脑浆 brains 粪便 excrement 蛤蟆 toad 恶臭 stink 蛆虫 maggot

肠子 intestine 狗屎 dogshit 感染 infection 老鼠 mouse 尸体 corpse 蟑螂 cockroach

脓肿 abscess 湿疹 eczema 便池 urinal 遗骸 remains 狐臭 hircus 耳屎 earwax

蜈蚣 centipede 腐烂 rot 痔疮 hemorrhoids 肛门 anus 肉瘤 sarcoma 痢疾 dysentery

鼻涕 snot 疱疹 herpes 僵尸 zombie 马桶 toilet 干尸 mummification 蛔虫 roundworm

臭虫 cimicid 蝎子 scorpion 痰桶 spittoon 黏液 mucus 虱子 louse 粉刺 pimple

细菌 germ 毒瘤 malignant tumor 溃疡 ulcer 尸骨 skeleton 瘟疫 plague 苍蝇 fly

Neutral words

脸谱 facial makeup 世俗 secularity 舒畅 comfort 整洁 tidiness 视角 perspective

日期 date 条目 entry 差别 difference 钢琴 piano 夙愿 long-cherished wish

奖牌 medal 港湾 harbor 细腻 exquisition 视觉 vision 事态 situation 法规 regulation

垂钓 fishing 百姓 common people 年糕 rice cake 风筝 kite 行踪 whereabouts

国徽 national emblem 顺序 order 护照 passport 麻绳 hemp rope 委婉 circumbendibus

凤凰 phoenix 池塘 pond 洋葱 onion 瓷器 porcelain 片刻 moment 喷泉 fountain

保安 security guard 柳树 willow 泡沫 foam 旅游 tourism 胭脂 rouge 番茄 tomato

清单 list 领带 tie 规则 rule 憧憬 longing 差异 discrepancy 简易 simplicity 人生 life

审阅 review 红酒 red wine 金融 finance 楼房 building 寺院 temple 考官 examiner

权力 power 鱼竿 fishing rod 前景 prospect 路途 road 顾问 consultant 发芽 sprouting

淋浴 shower 体操 gymnastics 拥挤 congestion

Vehicle names

公交 public transportation 汽车 car 小船 boat 单车 bicycle 卡车 truck

木船 wooden boat 推车 cart 渡轮 ferry 火箭 rocket 火车 train 地铁 subway

摩托 motorcycle 机车 locomotive 游艇 yacht 的士 taxi 电车 tram 轻轨 light rail

帆船 sailboat 快艇 speedboat 飞机 airplane 马车 carriage 巴士 bus 客车 coach

汽艇 motorboat 货车 wagon 拖车 trailer 缆车 cable car 校车 school bus

警车 police car 跑车 sports car 赛车 racing car 轿车 sedan 吉普 jeep 皮卡 pickup

飞艇 airship 飞船 spaceship 轮船 steamship 房车 RV 战舰 battleship 军舰 warship

游轮 cruise ship 货船 cargo ship 渔船 fishing boat 牛车 ox cart 动车 bullet train

高铁 high-speed train 叉车 forklift 战车 chariot 坦克 tank 潜艇 submarine

Appendix 3

Experiment 2. Normative study questionnaires

Correo Electrónico (opcional)

Email (optional)

Nombre (opcional)

Name (optional)

A continuación, se presentará una serie de frases cortas, en las que deberás seleccionar qué emoción te parece que describe mejor su contenido. En algunos casos, puede que la frase te sugiera más de una emoción, pero debes seleccionar una sola. En otros casos, quizá te parezca que la frase no se ajusta a ninguna emoción particular, en cuyo caso debes seleccionar 'neutral'. Veamos algunos ejemplos:

Next, a series of short sentences will be presented, in which you must select which emotion you think best describes its content. In some cases, the phrase may suggest more than one emotion, but you must select only one. In other cases, you may find that the phrase does not fit any particular emotion, in which case you should select 'neutral'. Let's see some examples:

Tu amigo tiene cáncer.

You friend has cancer.

	neutral *neutral*	tristeza *sadness*	alegría *happiness*	asco *disgust*	enfado *anger*
emoción *emotion*					

¿Qué tan seguro estás?

How sure are you?

	poco seguro *a little sure*		medio seguro *moderately sure*		completamente seguro *completely sure*
seguro *sure*					

Abres la puerta de tu casa.

You open the door of your house.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

How sure are you?

	poco seguro		medio seguro		completamente seguro
seguro					

En la primera frase, la emoción más evidente es 'triste' y debes señalarla. En la segunda frase, la respuesta más plausible es 'neutral'. Cuando hayas señalado una de las emociones, debes a continuación puntuar cuan seguro estás de tu elección en la escala que aparece debajo. De modo que si has elegido 'triste' en la primera frase el puntaje 5 indica que estás completamente seguro, el puntaje 1 que estás poco seguro, y los demás puntajes tendrán valores intermedios.

Cuando lo desees puedes seguir con las frases siguientes. Por favor, responde rápidamente, no dediques mucho tiempo a pensar en cada frase.

In the first sentence, the most obvious emotion is 'sad' and you should point it out. In the second sentence, the most plausible answer is 'neutral'. When you have indicated one of the emotions, you must then rate how sure you are of your choice on the scale that appears below. Therefore, if you have chosen 'sad' in the first sentence, score 5 indicates that you are completely sure, score 1 that you are not quite sure, and the other scores will have intermediate values.

You can continue with the following phrases when you want to. Please respond quickly, don't spend too much time thinking about each sentence.

Limpias el fregadero sin guantes.

You clean the sink without gloves.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Un perro se mea en tu pierna.

A dog pees on your leg.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Limpias el pañal cagado de un bebé.

You clean a baby's messy diaper.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Pisaste una mierda de perro.

You stepped on dogshit.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Vomitas después de beber vino.

You vomit after drinking wine.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Ves un cachorro comiendose su caca.

You see a puppy eating its poop.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Te limpias la nariz con un pañuelo sucio.

You wipe your nose with a dirty handkerchief.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Buscas un reloj en la bolsa de basura.

You look for a watch in the garbage bag.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Ves gusanos en la basura.

You see worms in the garbage.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Hueles a pescado podrido.

You smell like rotten fish.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Sientes una cucaracha en tu brazo.

You feel a cockroach on your arm.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Ves moscas en la sopa.

You see flies in the soup.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Te comes una chuleta podrida.

You eat a rotten cutlet.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Usas un váter sucio.

You use a dirty toilet.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Comes un gusano en la fruta.

You eat a worm in the fruit.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Sacas las tripas del pescado con tus manos.

You remove the guts from the fish with your hands.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro

seguro					

Suspendes el último examen de la carrera.

You fail the last exam of the semester.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Fracasas en una entrevista importante.

You fail an important interview.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

No puedes pagar la residencia.

You cannot pay for residency.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Te has perdido tu concierto favorito.

You have missed your favorite concert.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tus padres se divorciaron.

Your parents got divorced.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tus compañeros de clase te ignoran.

Your classmates ignore you.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Pasas la Navidad sólo.

You spend Christmas alone.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Pasas el día de San Valentín solo.

You spend Valentine's Day alone.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tu pareja te abandona.

Your partner leaves you.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Nadie viene a tu cumpleaños.

Nobody comes to your birthday.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tu perro ha muerto.

Your dog has died.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Asistes al funeral de un amigo.

You attend a friend's funeral.

	neutral	tristeza	alegría	asco	enfado

emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

El huérfano está llorando.

The orphan is crying.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

El niño de tus amigos muere de leucemia.

Your friend's child dies of leukemia.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tu abuela ha muerto.

Your grandmother is dead..

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tu actor favorito muere de cáncer.

Your favorite actor dies of cancer.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

No puedes consolar a tu deprimido amigo.

You cannot comfort your depressed friend.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tu casa queda destrazada por una inundación.

Your house is devastated by a flood.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Te has perdido el contacto con tus amigos.

You have lost contact with your friends.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Charlas con un amigo.

You chat with a friend.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Te subes a un avión.

You get on a plane.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Haces cola en un cine.

You stand in line at a movie theater.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Ves la televisión en casa.

You watch television at home.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro

seguro					

Montas en la bicicleta estática.

You ride the exercise bike.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Tomar el tranvía a la Universidad..

You take the tram to the University.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Caminas por la calle.

You walk down the street.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Te pones una chaqueta.

You wear a jacket.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Compras manzanas en el supermercado.

You buy apples at the supermarket.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Bebes un vaso de agua.

You drink a glass of water.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Lees los titulares del periódico.

You read the newspaper headlines.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Echas gasolina al coche.

You put gas in the car.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Envias un correo electrónico.

You send an email.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Llamas a un taxi por el móvil.

You call a taxi on your mobile.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Cierras la puerta de tu casa.

You close the door of your house.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Sacas una botella de agua de la nevera.

You take a bottle of water out of the fridge.

	neutral	tristeza	alegría	asco	enfado

emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Te bajas del bus en la parada.

You get off the bus at the stop.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Repasas los anuncios de la revista.

You go through the ads in the magazine.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Lees un libro en la biblioteca.

You read a book in the library.

	neutral	tristeza	alegría	asco	enfado
emoción					

¿Qué tan seguro estás?

	poco seguro		medio seguro		completamente seguro
seguro					

Correo Electrónico (opcional)

Email (optional)

Nombre (opcional)

Name (optional)

A continuación, debes evaluar una serie de frases que se refieren a situaciones variadas en una escala de tranquilidad-excitación. Es decir, que en cada frase debes valorar como te sentirías en esa situación. Por ejemplo:

Next, you must evaluate a series of sentences that refer to varied situations on a scale of tranquility-excitement. That is, in each sentence you must assess how you would feel in that situation. For example:

	1 muy tranquilo *very* *clam*	2	3 neutro *neutral*	4	5 muy excitado *very* *excited*
Una araña trepa en tu pierna. *A spider crawls on your leg.*					
Te sientas en una silla. *You sit in a chair.*					

El puntaje 5 indica que estás muy excitado, el puntaje 1 que estás muy tranquilo. En la primera frase, la situación más evidente es 'excitado' y debes señalar 5.En la segunda frase, la situación más plausible es 'tranquilo' y debes señalar 1. Los demás valores de la escala corresponderían a estados de calma o excitación intermedios.

Cuando lo desees puedes seguir con las frases siguientes. Por favor, responde rápidamente, no pases mucho tiempo pensando en cada frase. Es mejor que respondas atendiendo a tu primera impresión y recuerda que puedes utilizar todos los valores de la escala.

A score of 5 indicates that you are very excited and a score of 1 indicates that you are very calm. In the first sentence, the most obvious situation is 'excited' and you should select 5. In the second sentence, the most plausible situation is 'calm' and you should mark 1. The other values on the scale would correspond to intermediate states of calm or excitement.

You can continue with the following phrases when you want to. Please respond quickly, don't spend too much time thinking about each sentence. It is better that you answer based on your first impression and remember that you can use all the values of the scale.

	1 muy tranquilo	2	3 neutro	4	5 muy excitado
Limpias el fregadero sin guantes. *You clean the sink without gloves.*					
Un perro se mea en tu pierna. *A dog pees on your leg.*					
Limpias el pañal cagado de un bebé. *You clean a baby's messy diaper.*					
Pisaste una mierda de perro. *You stepped on dogshit.*					
Vomitas después de beber vino. *You vomit after drinking wine.*					
Ves un cachorro comiendose su caca. *You see a puppy eating its poop.*					
Te limpias la nariz con un pañuelo sucio. *You wipe your nose with a dirty handkerchief.*					
Buscas un reloj en la bolsa de basura. *You look for a watch in the garbage bag.*					
Ves gusanos en la basura. *You see worms in the garbage.*					
Hueles a pescado podrido. *You smell like rotten fish.*					

Sientes una cucaracha en tu brazo. *You feel a cockroach on your arm.*					
Ves moscas en la sopa. *You see flies in the soup.*					
Te comes una chuleta podrida. *You eat a rotten cutlet.*					
Usas un váter sucio. *You use a dirty toilet.*					
Comes un gusano en la fruta. *You eat a worm in the fruit.*					
Sacas las tripas del pescado con tus manos. *You remove the guts from the fish with your hands.*					
Suspendes el último examen de la carrera. *You fail the last exam of the semester.*					
Fracasas en una entrevista importante. *You fail an important interview.*					
No puedes pagar la residencia. *You cannot pay for residency.*					
Te has perdido tu concierto favorito. *You have missed your favorite concert.*					
Tus padres se divorciaron. *Your parents got divorced.*					
Tus compañeros de clase te ignoran. *Your classmates ignore you.*					

Pasas la Navidad sólo. *You spend Christmas alone.*					
Pasas el día de San Valentín solo. *You spend Valentine's Day alone.*					
Tu pareja te abandona. *Your partner leaves you.*					
Nadie viene a tu cumpleaños. *Nobody comes to your birthday.*					
Tu perro ha muerto. *Your dog has died.*					
Asistes al funeral de un amigo. *You attend a friend's funeral.*					
El huérfano está llorando. *The orphan is crying.*					
El niño de tus amigos muere de leucemia. *Your friend's child dies of leukemia.*					
Tu abuela ha muerto. *Your grandmother is dead.*					
Tu actor favorito muere de cáncer. *Your favorite actor dies of cancer.*					
No puedes consolar a tu deprimido amigo. *You cannot comfort your depressed friend.*					
Tu casa queda destrazada por una inundación. *Your house is devastated by a flood.*					

Te has perdido el contacto con tus amigos. *You have lost contact with your friends.*					
Charlas con un amigo. *You chat with a friend.*					
Te subes a un avión. *You get on a plane.*					
Haces cola en un cine. *You stand in line at a movie theater.*					
Ves la televisión en casa. *You watch television at home.*					
Montas en la bicicleta estática. *You ride the exercise bike.*					
Tomar el tranvía a la Universidad.. *You take the tram to the University.*					
Caminas por la calle. *You walk down the street.*					
Te pones una chaqueta. *You wear a jacket.*					
Compras manzanas en el supermercado. *You buy apples at the supermarket.*					
Bebes un vaso de agua. *You drink a glass of water.*					
Lees los titulares del periódico. *You read the newspaper headlines.*					

Echas gasolina al coche. *You put gas in the car.*					
Envias un correo electrónico.. *You send an email.*					
Llamas a un taxi por el móvil. *You call a taxi on your mobile.*					
Cierras la puerta de tu casa. *You close the door of your house.*					
Sacas una botella de agua de la nevera. *You take a bottle of water out of the fridge.*					
Te bajas del bus en la parada. *You get off the bus at the stop.*					
Repasas los anuncios de la revista. *You go through the ads in the magazine.*					
Lees un libro en la biblioteca. *You read a book in the library.*					

Appendix 4

Experiment 2. Selected Stimuli

Pseudowords

Aljuevo, almego, alfirda, alsasto, altorzo, altapo, alsudi, algifo, alfuso, alyape

Robina, robica, rofelu, ronago, ronina, ronico, rorano, rogima, rofeno, royafe

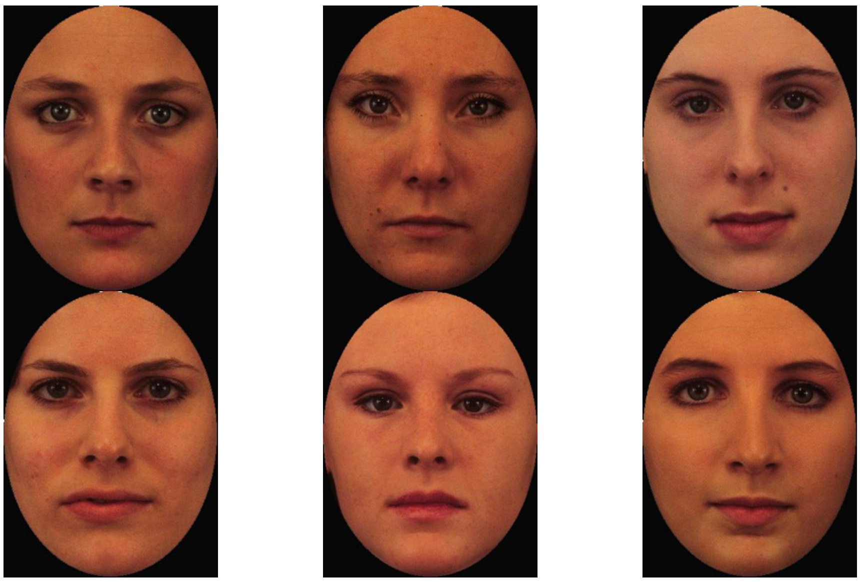
Lenuro, lerite, lefre, leriyo, leniaz, lerija, lengil, lesori, letuco, leceno

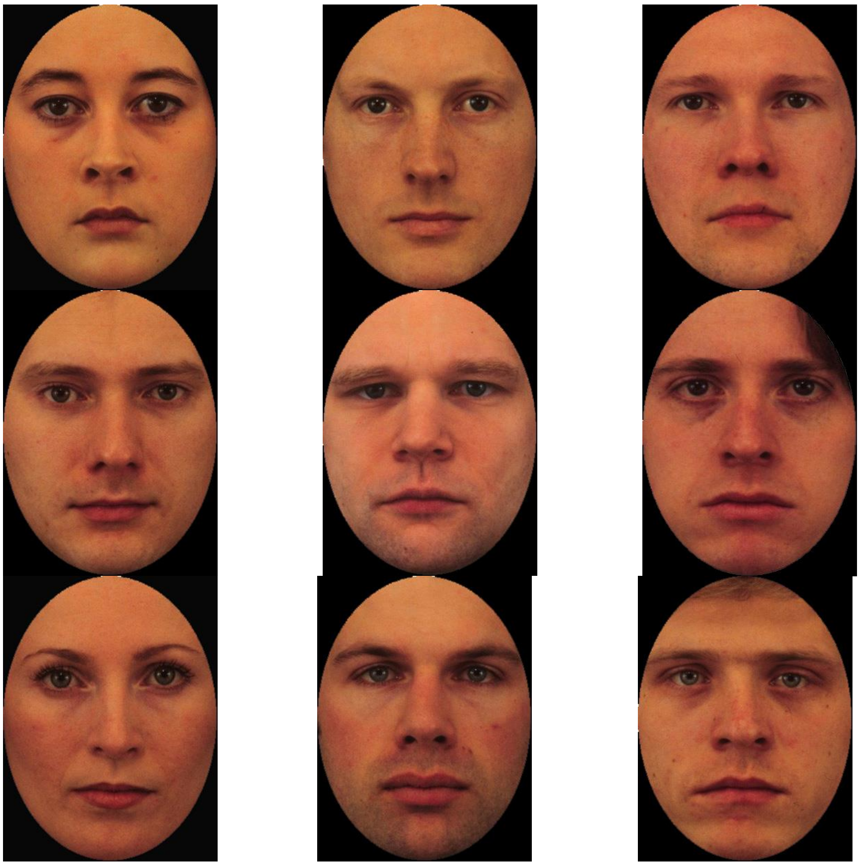
Faces

Disgust

Sadness

Neutral





Sentences

Disgust

Un perro se mea en tu pierna. *A dog pees on your leg.*

Limpias el pañal cagado de un bebé. *You clean a baby's messy diaper.*

Pisaste una mierda de perro. *You stepped on dogshit.*

Vomitas después de beber vino. *You vomit after drinking wine.*

Ves un cachorro comiendose su caca. *You see a puppy eating its poop.*

Te limpias la nariz con un pañuelo sucio. *You wipe your nose with a dirty handkerchief.*

Buscas un reloj en la bolsa de basura. *You look for a watch in the garbage bag.*

Ves gusanos en la basura. *You see worms in the garbage.*

Hueles a pescado podrido. *You smell like rotten fish.*

Sientes una cucaracha en tu brazo. *You feel a cockroach on your arm.*

Ves moscas en la sopa. *You see flies in the soup.*

Sacas las tripas del pescado con tus manos. *You remove the guts from the fish with your hands.*

Te comes una chuleta podrida. *You eat a rotten cutlet.*

Usas un váter sucio. *You use a dirty toilet.*

Comes un gusano en la fruta. *You eat a worm in the fruit.*

Sadness

Tus padres se divorciaron. *Your parents got divorced.*

No puedes consolar a tu deprimido amigo. *You cannot comfort your depressed friend.*

Tu casa queda destrazada por una inundación. *Your house is devastated by a flood.*

Tus compañeros de clase te ignoran. *Your classmates ignore you.*

Pasas la Navidad sólo. *You spend Christmas alone.*

Te has perdido contacto con tus amigos. *You have lost contact with your friends.*

Pasas el día de San Valentín solo. *You spend Valentine's Day alone.*

Tu pareja te abandona. *Your partner leaves you.*

Nadie viene a tu cumpleaños. *Nobody comes to your birthday.*

Tu perro ha muerto. *Your dog has died.*

Asistes al funeral de un amigo. *You attend a friend's funeral.*

El huérfano está llorando. *The orphan is crying.*

Tu actor favorito muere de cáncer. *Your favorite actor dies of cancer.*

El niño de tus amigos muere de leucemia. *Your friend's child dies of leukemia.*

Tu abuela ha muerto. *Your grandmother is dead.*

Neutral

Lees un libro en la biblioteca. *You read a book in the library.*

Te bajas del bus en la parada. *You get off the bus at the stop.*

Montas en la bicicleta estática. *You ride the exercise bike.*

Tomar el tranvía a la Universidad. *You take the tram to the University.*

Caminas por la calle. *You walk down the street.*

Te pones una chaqueta. *You wear a jacket.*

Compras manzanas en el supermercado. *You buy apples at the supermarket.*

Bebes un vaso de agua. *You drink a glass of water.*

Lees los titulares del periódico. *You read the newspaper headlines.*

Echas gasolina al coche. *You put gas in the car.*

Envias un correo electrónico. *You send an email.*

Llamas a un taxi por el móvil. *You call a taxi on your mobile.*

Repasas los anuncios de la revista. *You go through the ads in the magazine.*

Sacas una botella de agua de la nevera. *You take a bottle of water out of the fridge.*

Cierras la puerta de tu casa. *You close the door of your house.*

Appendix 5

Experiment 2. Supplementary analyses

Pseudoword Selection Test Response Accuracies of the Two Groups

For the Face Group, ANOVA analysis showed that there were significant differences among the three emotional categories, F (2, 78) = 5.492, p = .006, η^2 = .055. Response accuracies for neutral trials were significantly higher than those for sadness trials, t(39) = 3.602, p = .003. There was no difference between disgust and sadness trials, t(39) = 1.23, p = .226, or disgust and neutral trials, t(39) = 1.981, p = .109 (see Table 5).

For the Sentence Group, there was no significant difference among the three emotional categories, F(2, 80) = .728, p = .486, η^2 = .009 (see Table 5).

Pseudoword Matching Test Response Accuracies of the Two Groups

For the Face Group, ANOVA analysis showed no significant difference among the three emotional categories, F(2, 78) = 2.114, p = .128, η^2 = .026 (see Table 5).

For the Sentence Group, ANOVA analysis showed that there were significant differences among the three emotional categories, F(2, 80) = 5.759, p = .005, η^2 = .053. Response accuracies for sadness trials were significantly higher than those for neutral trials, t(40) = 3.726, p = .002. There was no difference between disgust and sadness trials, t(40) = 1.828, p = .15, or disgust and neutral trials, t(40) = 1.464, p = .151 (see Table 5).

Pseudoword Selection Test Response Time of the Two Groups

For the Face Group, ANOVA analysis showed that there were significant differences among the three emotional categories, F(2, 78) = 3.635, p = .031, η^2 = .012. Response time for sadness trials were significantly long than that for neutral trials, t(39) = 2.582, p = .041. There was no difference between disgust and sadness trials, t(39) = .562, p = .577, or disgust and neutral trials, t(39) = 1.952, p = .116 (see Table 6).

For the Sentence Group, there was no significant difference among the three emotional categories, F(2, 80) = 2.608, p = .08, η^2 = .009 (see Table 7).

Pseudoword Matching Test Response Time of the Two Groups

For the Face Group, ANOVA analysis showed no significant differences among the three emotional categories, F(2, 78) = 2.791, p = .068, η^2 = .013 (see Table 6).

For the Sentence Group, there was no significant difference among the three emotional categories, F(2, 80) = 1.315, p = .274, η^2 = .007 (see Table 7).

Within-Modality Generalization Test Response Time of the Two Groups

There was no significant difference between the two groups in response time, F(2, 80) = 2.195, p = .115, η^2 = .005.

For the Face Group, ANOVA analysis showed no significant differences among the three emotional categories, F(2, 78) = 2.778, p = .068, η^2 = .016 (see Table 6).

For the Sentence Group, there was no significant difference among the three emotional categories, F(2, 80) = 1.728, p = .184, η^2 = .006 (see Table 7).

Cross-Modality Generalization Test Response Time of the Two Groups

There was no significant difference between the two groups in response time, F(2, 80) = .825, p = .44, η^2 = .002.

For the Face Group, ANOVA analysis showed no significant differences among the three emotional categories, F(2, 78) = 1.325, p = .272, η^2 = .005 (see Table 6).

For the Sentence Group, there was no significant difference among the three emotional categories, F(2, 80) = 1.651, p = .198, η^2 = .012 (see Table 7).

General Comparison of Response Time of Acquisition Modalities

New Face Stimuli.

This comparison analyzed participants' response time on new face stimuli, i.e., the within-modality generalization test for the Face Group and the cross-modality generalization test for the Sentence Group.

There was no interaction effect between the two groups in response time, F(2, 80) = .213, p = .794, η^2 = .001.

New Sentence Stimuli.

This comparison analyzed participants' response time on new sentence stimuli, which would be the cross-modality generalization test of the Face Group and the within-modality generalization test of the Sentence Group.

There was no interaction effect between the two groups in response time, F(2, 80) = .013, p = .987, η^2 = .00.

Table 5. Means and Standard Deviations of response accuracies (percentage) in the pseudoword selection and the pseudoword matching tests as a function of learning group and emotion.

	FACE GROUP		SENTENCE GROUP	
	Pseudoword Selection	Pseudoword Matching	Pseudoword Selection	Pseudoword Matching
EMOTION	%	%	%	%
disgust	89 (12)	81.50 (16)	93.70 (13)	87.80 (11)
sadness	86.30 (14)	77.70 (16)	95.90 (8)	91.20 (10)
neutral	93 (9)	84 (16)	94.40 (8)	84.60 (13)
overall	89 (9)	81 (11)	95 (7)	88 (9)

Table 6. Means and Standard Deviations of response time (milliseconds) in the pseudoword selection, pseudoword matching, within-modality generalization, and cross-modality generalization tests of the Face Group.

	Pseudoword Selection RT	Pseudoword Matching RT	Within-Modality Generalization RT	Cross-Modality Generalization RT
EMOTION	ms	ms	ms	ms
disgust	1102 (332)	1269 (436)	1667 (919)	2029 (867)
sadness	1121 (382)	1275 (398)	1886 (844)	2148 (1121)
neutral	1031 (359)	1178 (320)	1629 (936)	2209 (1022)
overall	1085 (335)	1241 (350)	1727 (794)	2129 (924)

Table 7. Means and Standard Deviations of response time (milliseconds) in the pseudoword selection, pseudoword matching, within-modality generalization, and cross-modality generalization tests of the Sentence Group.

	Pseudoword Selection RT	Pseudoword Matching RT	Within-Modality Generalization RT	Cross-Modality Generalization RT
EMOTION	ms	ms	ms	ms
disgust	1018(313)	1129(316)	1574(717)	1969(786)
sadness	976(274)	1073(281)	1687(857)	2200(955)
neutral	947(327)	1079(326)	1732(917)	2039(913)
overall	986(283)	1094(276)	1664(771)	2069(749)

Appendix 6

Experiment 3. Selected stimuli

Pseudowords

aljuvado almegado alfirdado alsastado altorzado altapido alsudido algifado alfusado alyapado

robinado robicado rofeludo ronagado roninado ronicado roranado rogimado rofenado royafado

lenurado leritado lefreado leriyado leniazado lerijado lengilado lesorido letucado lecenado

bierado bicerado birenado bidelado bigirado bicitado biantado biverado biemado biscarado

Real words

congelado *frozen* asfalto *asphalt* ladrillo *brick* gimnasio *gym* ministro *minister*

despacho *office* documento *document* municipio *municipality* cuadrado *square*

martillo *hammer* conjunto *set* candidato *candidate* mercado *market*

elemento *element* producto *product* contexto *context* comercio *commerce*

sombrero *hat* camarero *waiter* impuesto *tax*

Vehicle names

autobús *bus* coche *car* bote *boat* bicicleta *bicycle* camión *truck* tren *train*

metro *metro* motocicleta *motorcycle* taxi *taxi* avión *plane* jeep *jeep*

triciclo *tricycle* astronave *spacecraft* tranvía *trolley car* yate *yacht*

sedán *sedan* cupé *coupe* locomotora *locomotive* canoa *canoe* helicóptero *helicopter*

Sentences used in the cross-modality generalization test of the learning session

Disgust

Un perro se mea en tu pierna. *A dog pees on your leg.*

Limpias el pañal cagado de un bebé. *You clean a baby's messy diaper.*

Pisaste una mierda de perro. *You stepped on dogshit.*

Vomitas después de beber vino. *You vomit after drinking wine.*

Ves un cachorro comiendose su caca. *You see a puppy eating its poop.*

Sadness

Tus padres se divorciaron. *Your parents got divorced.*

No puedes consolar a tu deprimido amigo. *You cannot comfort your depressed friend.*

Tu casa queda destrazada por una inundación. *Your house is devastated by a flood.*

Tus compañeros de clase te ignoran. *Your classmates ignore you.*

Pasas la Navidad sólo. *You spend Christmas alone.*

Neutral

Lees un libro en la biblioteca. *You read a book in the library.*

Te bajas del bus en la parada. *You get off the bus at the stop.*

Montas en la bicicleta estática. *You ride the exercise bike.*

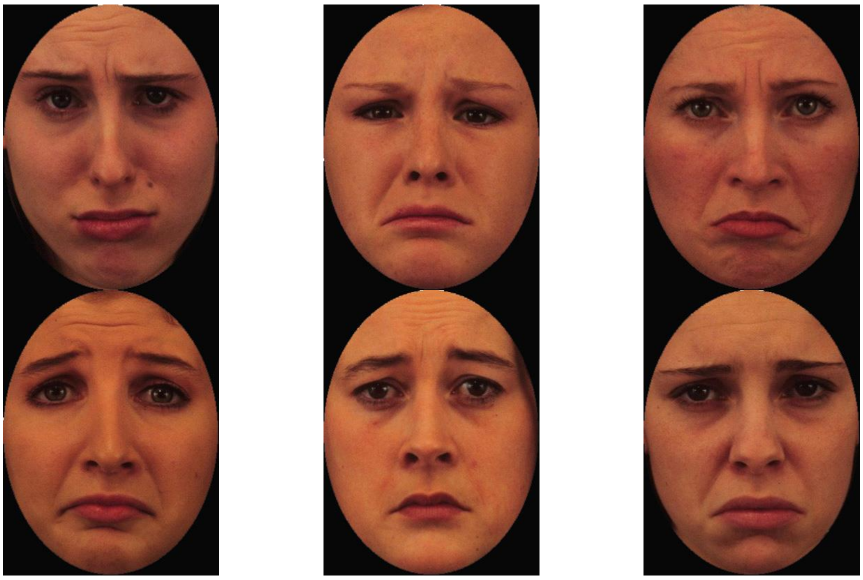
Tomar el tranvía a la Universidad. *You take the tram to the University.*

Caminas por la calle. *You walk down the street.*

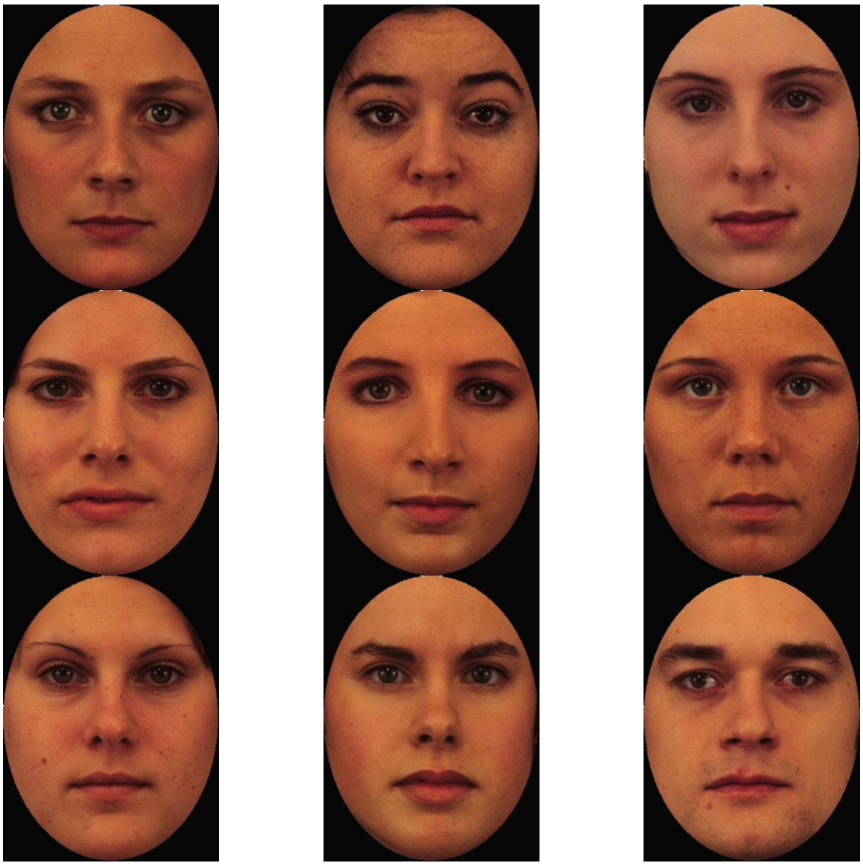
Faces

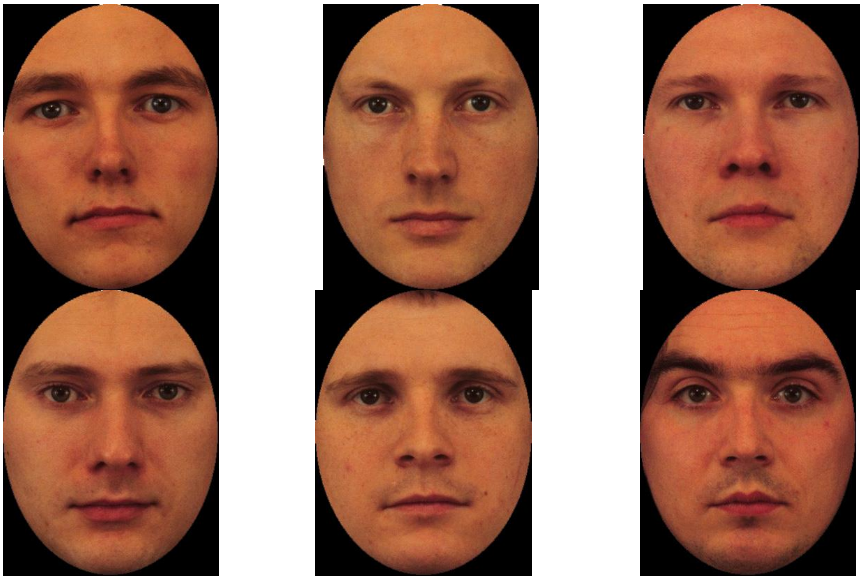
Disgust

Sadness



Neutral





Appendix 7

Experiment 3. Supplementary analyses

Pseudoword learning effect

The pseudoword learning effect was manifested through the LPC component with the time winodws varying in each condition.

Figure 6 illustrated the waveform and topography of the significant learning effect between disgusting pseudowords and unlearned new pseudowords: t (27) = 3.329, p = .003, *Cohen's d* = .629.

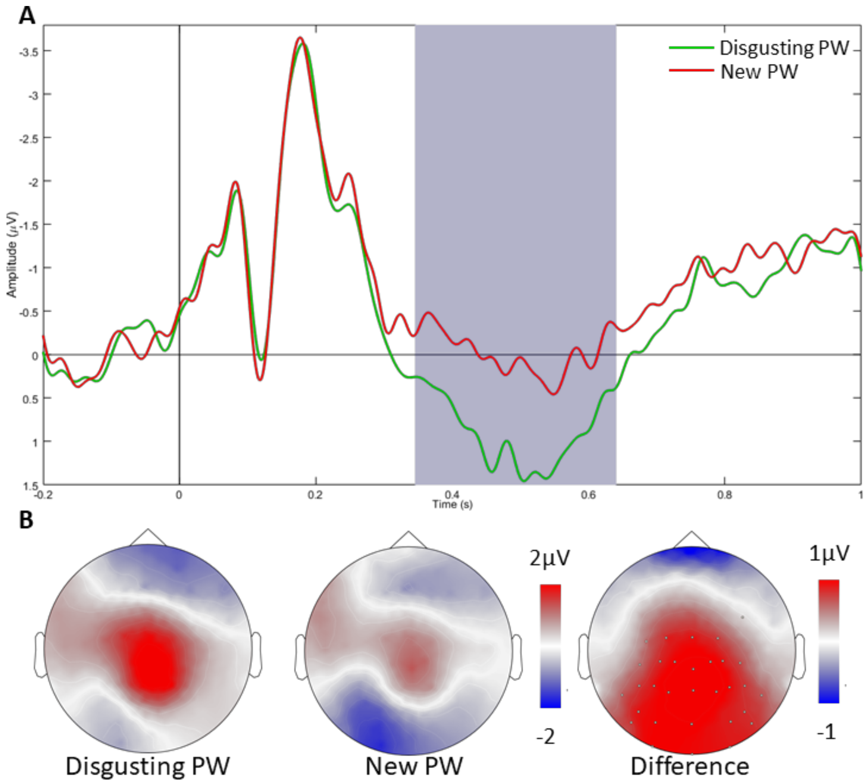


Figure 6. ERP results of the learning effect between disgusting pseudowords and new pseudowords (346 – 640 ms). (A) Average waveforms of disgusting pseudowords and new pseudowords in a cluster of electrodes manifesting significant differences (C3, C1, CZ, C2, FC4, CP5, CP3, CP1, CPZ, CP2, CP4, CP6, P7, P5, P3, P1, PZ, P2, P4, P6, P8,

PO7, PO5, PO3, POZ, PO4, PO6, PO8, O1, OZ, O2). (B) Topographical distributions of the LPC component for disgusting pseudowords, new pseudowords, and the difference between the two.

Figure 7 illustrated the waveform and topography of the significant learning effect between sad pseudowords and unlearned new pseudowords: t (27) = 4.423, p < .001, *Cohen's d* = .836.

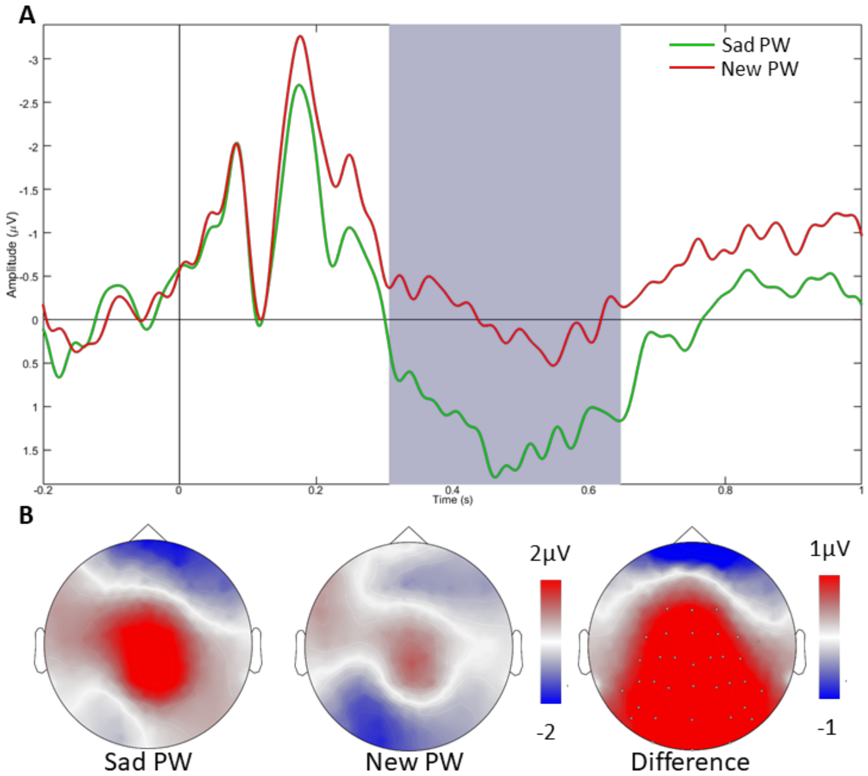


Figure 7. ERP results of the learning effect between sad pseudowords and new pseudowords (308 – 646 ms). (A) Average waveforms of sad pseudowords and new pseudowords in a cluster of electrodes manifesting significant differences (FC1, FCZ, FC2, C3, C1, CZ, C2, C4, C6, CP5, CP3, CP1, CPZ, CP2, CP4, CP6, P7, P5, P3, P1, PZ, P2, P4, P6, P8, PO7, PO5, PO3, POZ, PO4, PO6, PO8, O1, OZ, O2). (B) Topographical

distributions of the LPC component for sad pseudowords, new pseudowords, and the difference between the two.

Figure 8 illustrated the waveform and topography of the significant learning effect between neutral pseudowords and unlearned new pseudowords: t (27) = 5.394, $p < .001$, *Cohen's d* = 1.019.

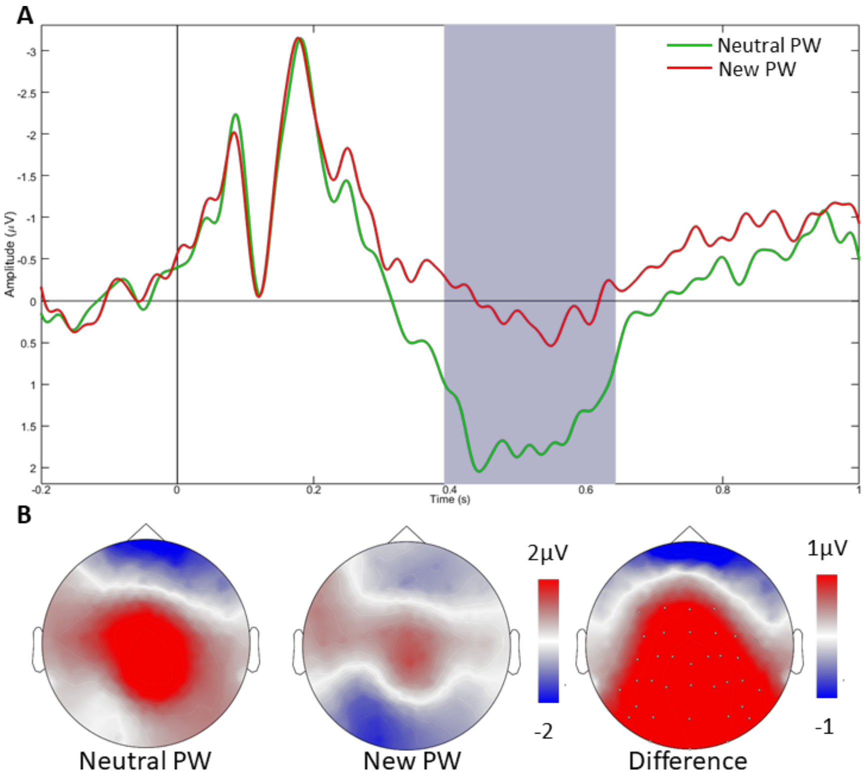


Figure 8. ERP results of the learning effect between neutral pseudowords and new pseudowords (308 – 646 ms). (A) Average waveforms of neutral pseudowords and new pseudowords in a cluster of electrodes manifesting significant differences (FC3, FC1, FCZ, FC2, C3, C1, CZ, C2, C4, C6, CP5, CP3, CP1, CPZ, CP2, CP4, CP6, P7, P5, P3, P1, PZ, P2, P4, P6, P8, PO7, PO5, PO3, POZ, PO4, PO6, PO8, O1, OZ, O2). (B) Topographical distributions of the LPC component for neutral pseudowords, new pseudowords, and the difference between the two.